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BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT

REPORT OF THE SCIENTIFIC REVIEW PANEL

January 15, 2002

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British Columbia Offshore Hydrocarbon Development: Report of the Scientific Review Panel

A report in two volumes

(Volume II: British Columbia Offshore Hydrocarbon Development: Volume II – Appendices to the Report of the Scientific Review Panel)

Submitted to the BC Minister of Energy and Mines, Hon. Richard Neufeld

January 15, 2002

Panel Members:

David Strong (Chair)	David Strong is Professor in the School of Earth and Ocean Sciences at the University of Victoria. He was President and Vice-Chancellor at the University of Victoria from 1990 to 2000. He serves on the governing council and the executive committee of the National Research Council of Canada and the Research Council of the Canadian Institute of Advanced Research. Strong is the past Vice-President of Memorial University in St. John's, Newfoundland, where he was also special adviser to the President. He was a Member of the Standing Advisory Committee on University Research of the Association of Universities and Colleges of Canada, and served on British Columbia's Advisory Council on Science and Technology and the Newfoundland and Labrador Advisory Council on Science and Technology, among others.
Patricia Gallagher	Patricia Gallaugher is Director of Continuing Studies in Science and Director of the Centre for Coastal Studies at Simon Fraser University. She was a Professor of biology at Memorial University and is co-editor of a volume on marine conservation, *Waters in Peril*. Gallaugher participated in the North American Commission for Environmental Cooperation workshop on aquatic invasive species in the spring of 2001. Gallaugher has a PhD in bioscience from Simon Fraser University.
Derek Muggeridge	Derek Muggeridge is Dean of the Faculty of Science at Okanagan University College, where he is also Associate Vice-President of Research. He is President of Offshore Design Associates Ltd., which provides specialist services in offshore safety and wave and ice structure interaction. Muggeridge is a Member of the Awards Committee of the Science Council of British Columbia and a Member of the Canadian National Committee / Engineering Committee on Oceanic Resources. He was the Director of the Ocean Engineering Research Centre at Memorial University. Muggeridge has a Bachelor of Science from California State Polytechnic University, and a Master's of Science and a PhD in aerospace engineering, both from the University of Toronto.

BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT

Executive Summary

On October 19, 2001 the British Columbia Minister of Energy and Mines appointed this panel to advise on four particular matters:

i) *"the scientific and technological considerations relevant to offshore oil and gas exploration, development and production;*

ii) *"further research or studies that should be undertaken to advance the "state of knowledge" on these considerations;*

iii) *"any specific government actions that should be taken prior to a decision on whether or not to remove the current provincial moratorium; and*

iv) *"any specific conditions or parameters that should be established as part of a government decision to remove the moratorium."*

Our response to the first two items forms the core of this report, based upon extensive reviews of previous reports and scientific literature, as well as a number of specially commissioned reports.

We identify a number of important knowledge gaps on which "further research or studies should be undertaken to advance the state of knowledge on these considerations", to allow for responsible "scientific and technological considerations relevant to offshore oil and gas exploration, development and production". In response to items (iii) and (iv) of our mandate, we provide some observations on the science and technology-based, but not inherently science and technology, issues of public policy related to matters such as capacity-building, regulation and monitoring.

The basic messages from this review are:

A. The prospective areas for oil and gas offshore British Columbia have many similarities with other jurisdictions around the world, and there is much to be learned from their experience. While BC is unique in the particular combination of components of its marine ecosystem, resources and coastal heritage, most of these can be found individually or in other combinations in other areas of offshore production. For example, eastern Canada and Alaska have a more severe climate; the Cook Inlet of Alaska is more confined; Alaska and California generally experience more severe earthquakes. Nevertheless, any offshore activities in British Columbia, at least in the inland waters between the Queen Charlotte and Vancouver Islands, would be near-shore activities, and any adverse environmental impacts would be quickly felt in coastal communities and habitats, and so would require rapid response and remediation.

B. Although the region is seismically active (Chapter 2), that is not considered to constitute any overwhelming risks for offshore exploration, development or production (Chapter 4).

C. Although risks of direct impacts on marine ecosystems may be small, there is poor understanding of potential long-term cumulative impacts on marine ecosystems of oil or gas spills or discharges from production activities, or of the impact of seismic exploration on marine mammals in particular and the ecosystem in general. These potential impacts may be of very low probability but may be catastrophic in the short term and carry serious and possibly irreversible consequences in the long term (Chapter 3).

D. Although the region is subject to intense storms as well as seismic activity (Chapter 2), present engineering knowledge, technology, industry practice and regulatory regimes can ensure that structures necessary for drilling and production activities are constructed to survive any foreseeable natural threats and to operate within acceptable standards (Chapters 4).

The panel is aware that in dealing with such matters as the cumulative impacts of human activities on marine ecosystems, the BC and Canadian governments have committed themselves to adopt a precautionary, ecosystem-based approach to integrated adaptive management. This panel endorses the Wingspread formulation of the precautionary principle, but also underlines the observation in the December 17, 2001 Lowell Statement on Science and the Precautionary Principle that emphasizes, "*The goal of precaution is to prevent harm, not to prevent progress.*" (See Appendix 20 in Volume II of the Report)

The remaining issues identified above can best be addressed in a concrete setting in assessment of proposals for specific activities to be undertaken, not in abstract or general terms. The panel concludes on the basis of its review that the existing blanket moratorium has served its purpose, but has also set back our understanding of the coasts and oceans of British Columbia. It is time now to return marine scientific research to levels appropriate for a modern advanced society in general terms, and particularly as a basis for comprehensive, balanced and inclusive deliberation and assessment of specific proposals for BC offshore activity.

In short, the panel endorses the concerns expressed in the JWEL and preceding reports about the possible impacts of exploration or drilling activities on marine ecosystems and associated human communities, but sees this concern not as an argument for a general prohibition on all offshore activity—that is, for maintenance of a blanket moratorium—but rather as a need to examine specific proposals for any human activities, including offshore hydrocarbon-related activities, carefully with respect to their location, timing and impacts on particular species or components of marine ecosystems over the long term, and against broadly conceived alternative strategies (Chapter 5).

In order to consider the science and technology dimensions of any decision on whether to remove the moratorium, the Panel was obliged to ask what the moratorium actually is, how it could be removed, and what would be the situation subsequently. These questions are not straightforward, but we believe the short answer to be, as the dictionary says, that the present moratorium is a temporary prohibition or suspension of an activity, in this case of activities related to exploration for hydrocarbon resources offshore British Columbia. It appears that the current moratorium could be ended simply with a provincial decision to that effect, and a federal announcement agreeing that bids for licenses or applications for permits to undertake exploratory work in specific parcels of offshore areas would be considered.

Thus, in the panel's understanding of the situation, it seems there actually is today no legislated moratorium formally in place, either federally or provincially. For the panel, the central point seems to be that the concerns with this 'current moratorium' are all procedural and perceptual, not scientific or technical. The sooner the Province can move on to careful consideration of concrete proposals from identifiable proponents, the sooner we will get into constructive assessment of the issues based on the scientific, social and ethical realities of the sea in its actual setting.

Were the present moratorium ended, any further action would presumably await concrete expressions of interest in the development potential of specific sites. There would be several important things that would need to be done before there could be any expectation of investor interest, public or private, in proposals for exploration or development work in the BC offshore. While they are not strictly scientific or technical issues, they are germane to points (iii) and (iv) of our mandate, and we endorse the following preconditions that have been spelled out already by industry, First Nations, and others. These include:

> Development of an integrated federal-provincial regulatory framework. (The panel is aware that the Canadian Environmental Assessment Act and the British Columbia Environmental Assessment Act are undergoing review and amendment, and that the existing Canada-British Columbia bilateral accord on harmonized assessment expires in April 2002 and must be renegotiated.)
>
> Negotiation of a Pacific Accord that provides for agreed federal-provincial revenue sharing and other fiscal and management arrangements.

> Clear delineation of sensitive or vulnerable areas essential to preserve biodiversity and ensure ecosystem integrity, so that industry and others will be able to develop proposals for offshore activity with a clear initial understanding of any boundary conditions or restrictions.
>
> Strengthening and development of scientific and technical capacity to build baseline data and assess the state of the ecosystem, including natural and human components, and capacity also to undertake quantitative risk analysis, valuation and assessment spanning the full range of strategic options.

Thus, in the above context, the decision as to whether or not to remove the present blanket moratorium seems to be again one of procedure, more than science and technology.

To the general question posed to it, therefore, this panel concludes overall that, while there are certainly gaps in knowledge and needs for intensification of research as well as for a commitment to building comprehensive baseline information systems and to long-term monitoring, these do not preclude responsible deliberations on the questions related to offshore oil and gas exploration and development. There is no inherent or fundamental inadequacy of science or technology, properly applied in an appropriate regulatory framework, to justify a blanket moratorium on such activities. With a firm commitment to comprehensive assessment of any proposals for specific offshore activities as provided in the existing legislative framework, and continuing commitment to ongoing principles of adaptive management and sustainable development, the existing policies maintaining an ongoing moratorium on hydrocarbon exploration and development offshore British Columbia can responsibly be ended.

ACKNOWLEDGEMENTS

The logistic and editorial, as well as the 'non-scientific' aspect of this review have been supremely managed by The Maritime Awards Society of Canada. This is a registered charitable organization established to provide scholarships for Canadian university graduate students in marine and coastal affairs. At present MASC donations support scholarships at four universities: Victoria, Memorial, Dalhousie and Calgary. In addition, MASC has undertaken to provide a public service through annual workshops, public conferences, and other educational activities that are designed to raise awareness and enhance understanding of public policy issues related to the ocean in general and to Canada's coastal waters. The panelists are pleased to acknowledge the MASC contribution, and more specifically those of Mr. Justin Longo, Executive Director and Professor Douglas Johnston, Program Coordinator.

We are grateful to the many people who have generously provided us with reports, advice, information and opinions, and hope that they are all identified in the following list.

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Dr. Richard Carson, Oceans Directorate, Fisheries and Oceans Canada, Vancouver
Dr. Ross Chapman, School of Earth and Ocean Sciences, University of Victoria
Dr. Sandy Colvine, Director Pacific Geoscience Centre
Dr. Ralph G. Currie, Pacific Geoscience Centre, Sidney Subdivision
Dr. Denis Connor, Chairman and CEO, QuestAir Technologies
Dr. Rod Dobell, Professor, School of Public Administration, University of Victoria
Dr. Robert W. Durie, Victoria
Dr. Dan Esler, Centre for Wildlife Ecology, Simon Fraser University
Dr. Richard Haedrich, Memorial University, Newfoundland
Dr. Don Hodgins, President, Seaconsult Ltd, Vancouver
Dr. Falk Huettmann, Centre for Wildlife Ecology, Simon Fraser University
Dr. Roy Hyndman, Pacific Geoscience Centre, Sidney Subdivision
Marji Johns, Principal, Pacific PaleoQuest
Dr. Ian Jordaan, Ian Jordaan and Associates, St. John's Newfoundland
Dr. John Madden, Chairman, NEPTUNE Canada, Vancouver
Michael Maser, Blue Energy Canada Inc., Vancouver BC
Patrick O'Rourke, Assistant Deputy Minister, BC Ministry of Energy and Mines
Dr. Craig Orr, Centre for Coastal Studies, Simon Fraser University
Dr. Stanley Rice, National Marine Fisheries Service, Juneau, Alaska
Dr. Gary C. Rogers, Pacific Geoscience Centre, Sidney Subdivision
Dr. Kristen Rohr, Rohr Geophysics, North Saanich, BC
Dr. Verena Tunnicliff, School of Earth and Ocean Sciences, University of Victoria
Bou van Oort, Senior Advisor, BC Ministry of Mines and Energy
Dr. Lindy Weilgart, Dalhousie University, Halifax
Dr. Michael Whiticar, School of Earth and Ocean Sciences, University of Victoria
Allen Wood, Allen Wood Consulting, North Vancouver
Dr. Mark Zacharias, Ministry of Sustainable Resource Management, Victoria

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CHAPTER ONE INTRODUCTION

1.1 Background

On October 19th, 2001, the British Columbia Minister of Energy and Mines appointed this Panel to provide advice on four related matters (see Appendix 1 in Volume II of this Report):

the scientific and technological considerations relevant to offshore oil and gas exploration, development and production;

further research or studies that should be undertaken to advance the "state of knowledge" on these considerations;

any specific government actions that should be taken prior to a decision on whether to remove the current provincial moratorium; and

any specific conditions or parameters that should be established as part of a government decision to remove the moratorium.

At the same time this Panel was requested to take into account the findings of the report on the status of offshore development technologies that was produced, under contract with the BC Ministry of Energy and Mines, by the consultancy firm Jacques Whitford Environment Limited (JWEL), and made public in October 2001. In reviewing the JWEL report, this Panel has also undertaken to examine and comment upon several earlier reports that seem equally germane to its mandate:

the **1986 "Offshore Hydrocarbon Exploration"** federal/provincial review of conditions that should attach to proposed programs of exploratory drilling off the coast of BC, and the extraneous events that led to the placing of moratoria on such development for the balance of the 1980s;

the **1992/93 SPARK** review for the Science Council of British Columbia outlining the potential for technological and economic opportunities from ocean-related activities;

the **1996 COFRI** report reviewing the 1986 recommendations in the new context of another decade;

the **1998 AGRA** report re-examining the continuing moratorium, on which was based the **2001 JWEL** report, again reviewing the question of the continuing provincial moratorium;

reports of the BC Northern Development Commission;

a compendium of papers, reports, notes and abstracts compiled as the "**Briefing Book**" for the Workshop "Exploring the Future of Offshore Oil and Gas Development in BC: Lessons from the Atlantic", Simon Fraser University, May 17-18, 2000;

a report from the Maritime Awards Society of Canada, "**B.C. Offshore Hydrocarbon Development: Issues and Prospects**", released in early 2001.

numerous reports and documents on the **web-sites** of organizations identified in Appendix 2.

and not least, a number of **interviews and special reports** commissioned especially for this review, as identified and/or provided in the Acknowledgements and Appendices.

It is clear from the first two terms of reference that this Panel should concentrate chiefly on the offshore-related research literature of the science-and-technology community. However, the Panel interprets the third and fourth terms of reference as somewhat broader in scope, permitting technical or cognate considerations and recommendations that seem relevant to a government decision whether or not to remove the current provincial moratorium. Some of these considerations are incorporated into the main text of this Report, and others are included in Volume II of this Report (the Appendices). The Panel's recommendations are brought together in Chapter Five.

1.2 The General Context

Despite the vastness of its interior across the breadth of North America, Canada is a coastal nation. As possessor of the longest coastline, Canada has an enormous, virtually unequalled, stake in ocean affairs. During the seminal, law-making negotiations beginning in 1967, and continuing throughout the Third UN Conference on the Law of the Sea (1973-82), Canadian diplomats achieved impressive gains through global consensus on a massive extension of coastal state jurisdiction. As a result, Canada is the beneficiary of the second largest continental shelf, as defined under the new international law of the sea.

British Columbians have always looked to the sea for sustenance and transport. Prior to contact with Europeans, the original coastal communities of these territories nurtured a special cultural relationship with the spirits and resources of the Pacific offshore. In more recent times the people of BC have developed one of the largest ports in North America, and, taking advantage of their commercially strategic location, have created important modern industries based on vessel and underwater technologies.

Table 1-1. Estimated Reserves in Sedimentary Basins in British Columbia (Source - Preliminary Report of the Energy Policy Task Force)

Basin Name	Gas (TCF)	Oil (million barrels)	Coalbed Methane(TCF)
Western Canada Sedimentary Basin	50.0	265	60.0
Whitehorse/Bowser	8.3	2500	8.0
Quesnel/Nechako	9.5	5100	1.0
Fernie	0.4	88	19.0
Georgia/Vancouver Island	1.0	0	6.5
Total	70.3*	7953	94.5

* The total for this column differs from the arithmetic sum of the above numbers due to modelling discrepancies

Proposals for an offshore oil and gas industry off the coast of British Columbia have been raised for half a century. It may be worth noting that BC already produces more than twice the volume of natural gas than it consumes, with significant reserves estimated for a number of on-land sedimentary basins (Table 1-1, Figure 1-1). In the past year the total volume of provincial oil and gas revenues exceeded $1.8 billion, with approximately $1.3 billion derived from natural gas royalties. In 1999 approximately 14,500 people were directly employed by the oil and gas industry in the province. So it is logical to consider BC's offshore hydrocarbon resources as a possible extension of one of its most valuable, job-creating industries.

The Geological Survey of Canada has estimated that in the offshore sedimentary basins (Figure 1-1) there may be as much undiscovered hydrocarbon reserves as 9.8 billion barrels of oil (BBL) and 25.9 trillion cubic feet

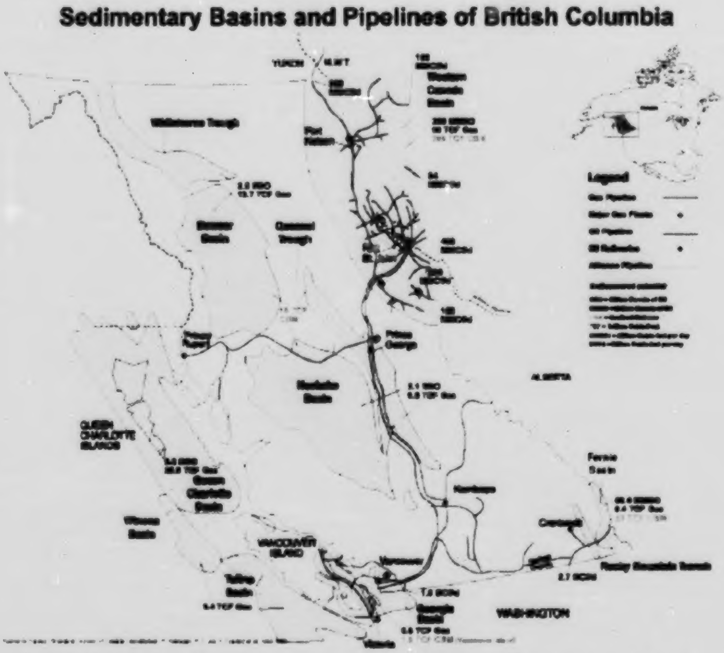

Sedimentary Basins and Pipelines of British Columbia
YUKON
N.W.T
Western Canada Basin
Whitehorse Trough
Fort Nelson
Legend
Bowser Basin
Quesnel Trough
Prince Rupert
Prince George
Nechako Basin
ALBERTA
QUEEN CHARLOTTE ISLANDS
Queen Charlotte Basin
Winona Basin
VANCOUVER ISLAND
Tofino Basin
Vancouver
Georgia Basin
Victoria
Kamloops
Fernie Basin
Cranbrook
Rocky Mountain Trench
WASHINGTON

Figure 1-1. Map showing on-land and offshore sedimen-tary basins and pipelines of British Columbia (Source: Preliminary Report of the Energy Policy Task Force)

(TCF) of gas in the Queen Charlotte Basin, 9.4 TCF in the Tofino and Winona Basins, and 6.5 TCF of gas in the Georgia Basin. Such estimates can only be confirmed by drilling, which must be preceded by and based upon sophisticated scientific and technical surveys, which in turn will only be carried out if permitted by the governments of British Columbia and Canada. The first step in such a process would be for the British Columbia government to decide whether or not to remove the moratorium, which has restricted such surveys and subsequent exploration activity since 1959.

Given the science-and-technology focus of its mandate, the Panel has avoided excursions into matters of policy, but since the line between technical and non-technical is sometimes thin and wavering, observations on public policy issues referred to in the terms of reference are offered from a science-and-technology perspective, mostly in Chapters Five.

Nevertheless, we must note that oil pollution of the oceans derives not from offshore oil and gas exploration and development activities, but from shipping and land-based activities (see Figure 1-2). The Province of British Columbia's November 1989 *Report to the Premier on Oil Transportation and Oil Spills* (commonly referred to as the "David Anderson Report"), and many others world-wide, correctly recognized the importance of shipping as the main agent of marine oil pollution and recommended that only double-hulled tankers should be used for transport of oil and gas. This report also led to a renewal of the moratorium. This Panel feels that attention would more appropriately be directed to sub-standard shipping, rather than to the much more intensely regulated offshore oil and gas regime.

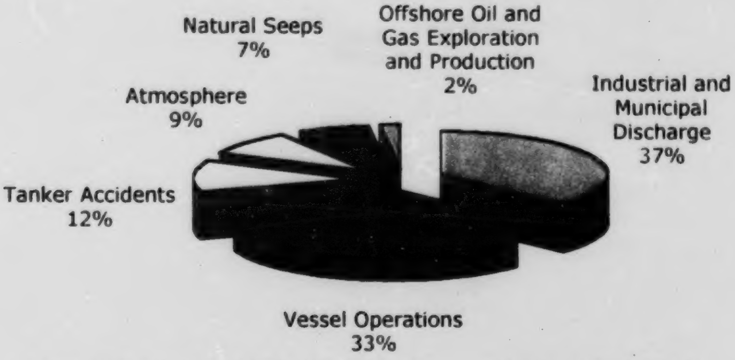


Figure 1-2. Sources of oil pollution in the oceans (from JWEL, 2001)

1.3 The Relevance of Offshore Development Experience in Other Districts

A conscientious re-examination of the offshore moratorium issue in British Columbia should take stock of experience elsewhere. Since the late 1930's, when the era of offshore oil production began, thousands of wells have been drilled in relatively shallow and not-so-shallow waters, covering oil-bearing areas of the continental shelf in virtually all regions of the world. For over 60 years the oil and gas industry has been active in the offshore, and is now producing in all climate zones, in many kinds of geological, oceanographic and climatic conditions, and in a wide variety of coastal ecosystems. There is no doubt that such activities have had negative impacts, environmental and otherwise, particularly in the earlier years, due to accidents, carelessness, and a plain lack of knowledge. It is also true that new knowledge, new designs, sophisticated regulation and greater public awareness and concern have continued to result in dramatic advances and improvements in offshore exploration and production, particularly over the last decade. These have, however, been either of a generic nature and general applicability to any region including BC, or of a site-specific nature, essential and useful only to the particular site of exploration or production.

The immediate areas of interest for offshore oil and gas exploration in BC are the Queen Charlotte Basin (QCB), and those to the south (see Figure 1-1). Coastal conditions in these waters are variable, ranging from dynamic beaches with extensive sand flats to steep cliffs and deep fjords. Similar conditions are found in other regions, and we note in particular four coastal regions which seem to have particular relevance to the offshore development issues in British Columbia.

First, the Canadian oil industry, the federal government of Canada, and the provincial governments of Newfoundland and Labrador and of Nova Scotia have, for more than thirty years, been acquiring first-hand experience in the offshore waters of Atlantic Canada in:

scientific, environmental and technical research;
monitoring and assessment;
technological applications;
local community planning and development;
the design and implementation of strict regulatory regimes governed by joint federal-provincial agencies established for that purpose; and
day-to-day operational arrangements worked out between these agencies and the private sector.

The modern era of oil and gas development in Atlantic Canada began in the early 1960s. Since then more than 300 exploratory and development wells have been drilled in Atlantic Canadian waters. Cumulatively, this drilling and seismic activity alone has generated nearly $8 billion in investment expenditures and has resulted in the creation of more than 100,000 jobs throughout the region. More than $14 billion has been committed to the development of upstream and downstream oil and gas projects since 1990.

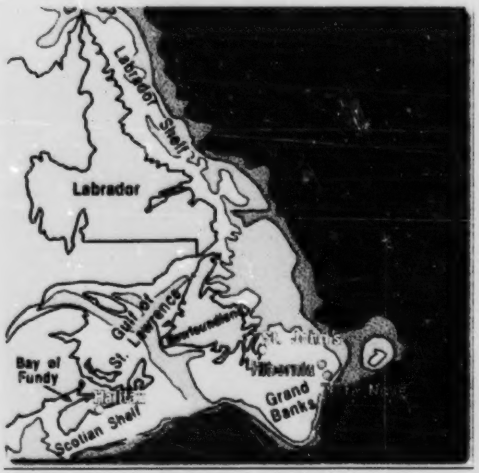


Figure 1-3. Setting of offshore oil and gas plays in eastern Canada (Source CNOPB)

Offshore Atlantic Canada is now firmly established in Canada's petroleum sector, and some of the world's major oil and gas companies have embarked upon aggressive and ambitious exploration and development programs in these waters. Since 1995 more than $700 million in exploration commitments have been announced for four regions within the Atlantic Canadian offshore: the Jeanne d'Arc Basin, Scotian Shelf, Sub-Laurentian Basin and the St. Pierre Bank (Figures 1-3 and 1-4). While there are differences in geological and other environmental aspects of the Atlantic offshore, it is of critical importance in providing a well-established regulatory framework on which to build for any BC offshore oil and gas exploration and development.

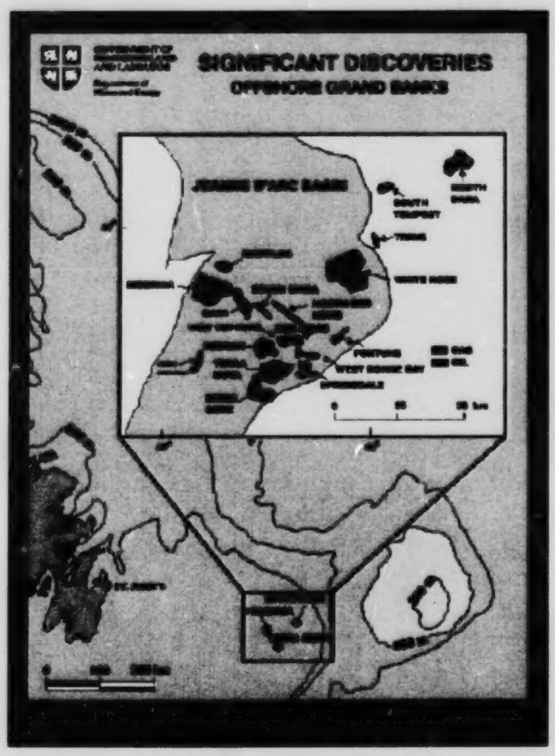


Figure 1-4. Detail of significant discoveries for Newfoundland and Labrador. (source CNOPB)

Second, and more directly relevant, it is important also to learn from the experience off the coast of Alaska, particularly the Cook Inlet, which is so close and, despite some significant and more severe conditions such as ice, snow, and glacial outwash, has so many direct geological and environmental similarities. Production began in Cook Inlet in 1957, mostly involving offshore platforms with pipelines to terminals on both sides of the Inlet. Total petroleum resources of the Cook Inlet Basin have been estimated about 2.2 BBL of oil and 10TCF of gas, with individual fields comparable in size to those projected for the QCB. Other production in Alaska was subsequently extended to the North Slope, where 13 BBL have been produced since 1973. More recently exploration and development activities have been expanded to the offshore waters of the Beaufort Sea, with first production at the BP Northstar Project on November 1 of 2001.

Third, oil and gas production in the state of California occurs in an earthquake-prone regime that has substantial geological similarities to that of BC, and the Queen Charlotte Basin in particular. These characteristics are reviewed in Chapter Two.

Fourth, the most comprehensive regional offshore operating experience of relevance to BC is almost certainly that which has accumulated since the 1960's in the North Sea (Figure 1-5). As this experience has been incorporated into the Atlantic Canada regulatory regime, we do not give it further attention in this review, other than to point out that the waters of the Queen Charlotte Basin between Dixon Entrance and Hecate Strait experience weather and hydrographic conditions comparable with those of the North Sea.

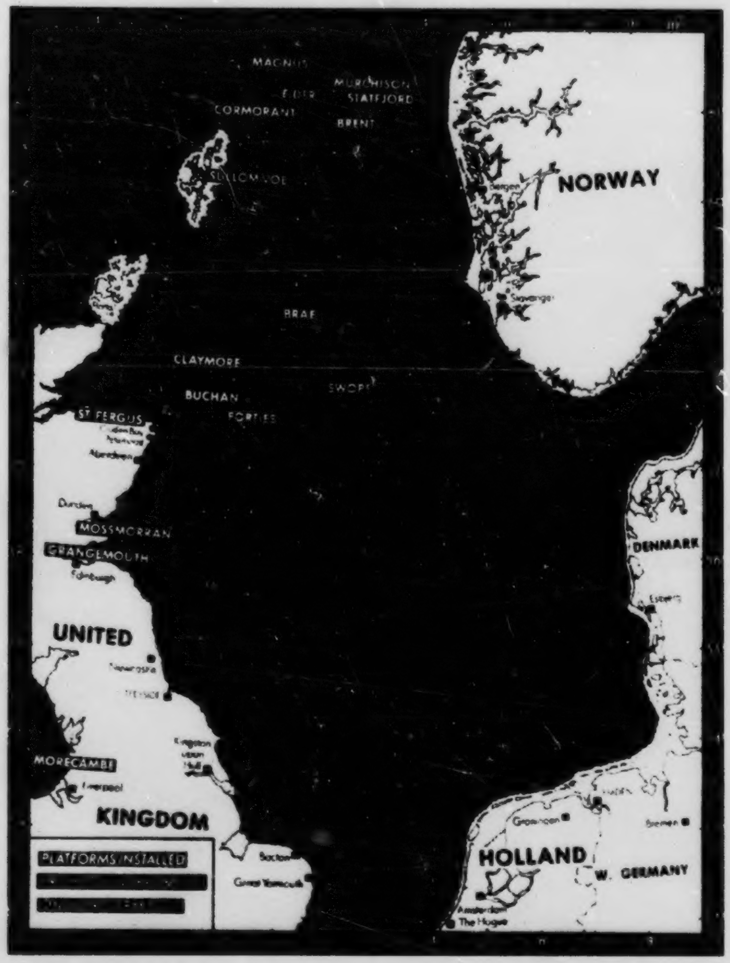

MAGNUS
EIDER
MURCHISON
STATFJORD
CORMORANT
BRENT
SULLOM VOE
NORWAY
BRAE
CLAYMORE
BUCHAN
FORTIES
ST FERGUS
Aberdeen
Dundee
MOSSMORRAN
GRANGEMOUTH
Edinburgh
DENMARK
Esbjerg
UNITED
Newcastle
Kingston upon Hull
MORECAMBE
Liverpool
KINGDOM
PLATFORMS INSTALLED
Bacton
Great Yarmouth
Groningen
Bremen
HOLLAND
W. GERMANY
Amsterdam
The Hague

Figure 1-5. Oil and gas activities in the North Sea (from Mathew Hall Engineering, in "The North Sea Platform Guide" Oilfield Publications Ltd.)

1.4 Roles of Ocean Science and Technology

Some idea of the complexity of the science and technology that is required at each stage from exploration to production of offshore oil and gas is given in Figure 1-6, and Appendix 4, where some of these terms are defined.

Because the field is so vast and our time was limited, we have necessarily been selective in conducting a review of this kind. Nevertheless, we note that decision-making is based on a sound understanding of science and technology at all phases in any current offshore production area (see Appendix 5), from the preliminary phase prior to the first decision, whether or not to permit seismic studies and exploratory drilling, right through all the subsequent stages of planning, project design, assessment, installation, production, and post-production decommissioning of platforms and other facilities.

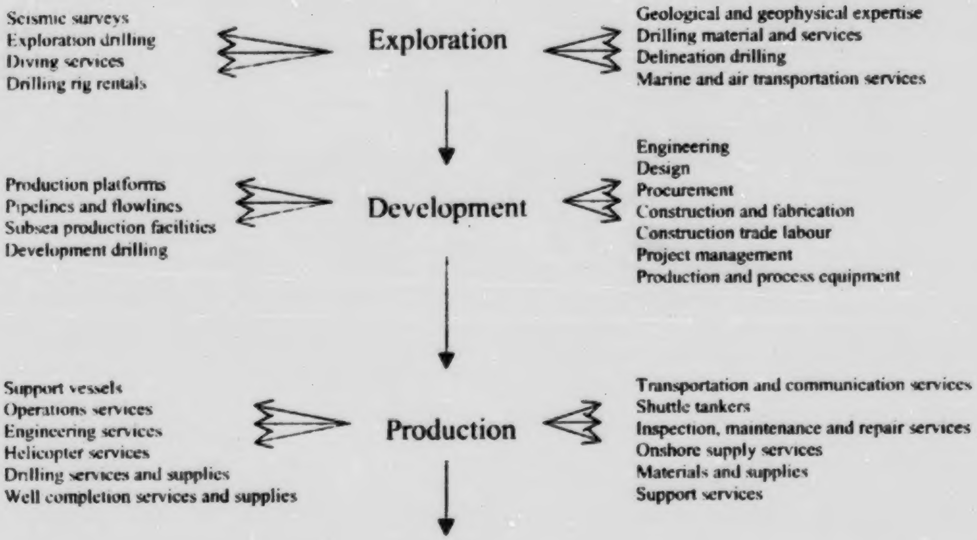

Seismic surveys
Exploration drilling
Diving services
Drilling rig rentals
Exploration
Geological and geophysical expertise
Drilling material and services
Delineation drilling
Marine and air transportation services
Production platforms
Pipelines and flowlines
Subsea production facilities
Development drilling
Development
Engineering
Design
Procurement
Construction and fabrication
Construction trade labour
Project management
Production and process equipment
Support vessels
Operations services
Engineering services
Helicopter services
Drilling services and supplies
Well completion services and supplies
Production
Transportation and communication services
Shuttle tankers
Inspection, maintenance and repair services
Onshore supply services
Materials and supplies
Support services

Figure 1-6. "Oil and Gas Value Chain" and technical expertise required at the up-stream stages of exploration, development and production of offshore oil and gas. (Source: NOIA, 1998)

The review by this Panel belongs to the preliminary phase, prior even to any start of exploration. At later stages of the process, it will become necessary to integrate and interpret more closely the results of regional and site-specific research that would need to be done in order to provide specific scientific foundations for risk assessment and appropriate design. Regimes of regulatory requirements will have to be framed around what is known about the local resource, the scale of production proposed, the types of technologies to be deployed, and the nature and vulnerability of the affected ecosystem. If there is a decision to lift the moratorium and proceed further, a long and continuous series of more focussed scientific and technical evaluations will become an integral part of the entire process, which, judging by the experience in other regions, would involve at least the stages of approval as set out for the Newfoundland offshore (Appendix 5).

However, at this preliminary stage, when the extent and locations of the offshore resources are still uncertain, and the Panel has been asked to address the blanket moratorium, it is necessary to conduct a review primarily within a generic frame of reference to describe the state of knowledge in offshore-related science and technology. Reference to regional and site-specific research is made only with a view to identifying knowledge gaps, setting research priorities, and determining measures that should be taken to ensure that technically appropriate standards will be achieved and maintained in the event of a government decision to proceed with the lifting of the BC moratorium.

CHAPTER TWO PHYSICAL SCIENCES

The successful exploration for oil and gas and the subsequent development and production stages depend upon a solid understanding of the geological environment, particularly the formation and development of hydrocarbon-bearing sedimentary basins and the geotechnical characteristics of the production site. Much of our understanding of the offshore sedimentary basins shown in Figure 1-1 has come from on-land geological mapping, which was extrapolated into the basins to aid in the interpretation of information obtained by more remote means. Within offshore basins, where most geological information is of necessity obtained by remote or proxy measurements, virtually all branches of the physical sciences - physics, chemistry and mathematics - are brought to bear, particularly through their specific applications in geophysics, geochemistry and information processing. These requirements in BC have to date depended upon the cooperation of many scientists in federal, provincial and university laboratories, particularly in the absence of any industrial involvement. Definitions of some of the more important terms are provided in Appendix 4, although we recognize that a report of this nature necessitates specialized language to some degree.

As can be seen in Figure 1-1, there are several offshore sedimentary basins in BC. While the others are briefly reviewed below, the main focus of early attention, and therefore of this Report, is on the Queen Charlotte Basin.

2.1 Geological Environment

2.1.1 The Georgia Basin

Limited drilling has been conducted, without commercial success, within the onshore regions of the Georgia Basin, both on eastern Vancouver Island and in the Fraser Valley (Figure 1-1). Of the 122 wells drilled since the turn of the century, most were water wells and only 16 reached depths in excess of 1,000 metres. Therefore, most of the basin's potential remains unevaluated. Recent resource assessment by the Geological Survey of Canada has estimated that as much as 6.5 TCF of in-place natural gas exists in three conceptual play types within the confines of the Georgia Basin, about two-thirds (3.55 TCF) being in Canada and one-third in Washington state. Of this, the median estimate of gas potential for Canada would be about 1.39 TCF. Available geochemical information indicates there is little potential for oil. One should be aware that there is some disagreement about these estimates, others suggesting that they could be substantially lower.

2.1.2 The Winona-Tofino Basin

The Tofino assessment region of the Geological Survey of Canada combines both the Winona and Tofino Basins (Figure 1-1). The main potential is indicated for the Tofino Basin from on-shore gas shows on the Olympic Peninsula, and is estimated at a median value to be 9.4 TCF of gas in-place in a single defined play type.

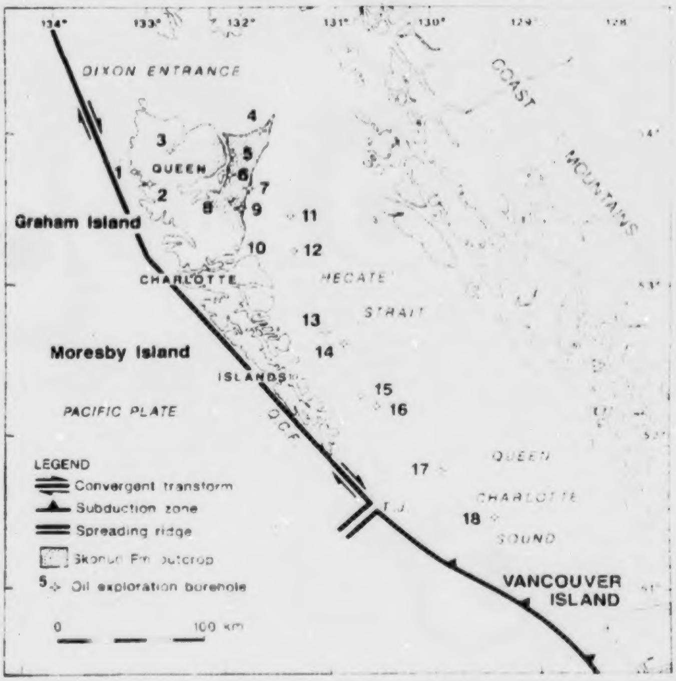
2.1.3 The Queen Charlotte Basin (QCB)

The QCB (Figure 2-1) is the largest Tertiary basin on Canada's West Coast, representing an area of approximately 80,000 km^2 (500 km long, 150 - 200 km wide). It includes (i) Queen Charlotte Islands, (ii) offshore areas of Hecate Strait; (iii) Queen Charlotte Sound; and (iv) Dixon Entrance.

The QCB is bounded to the south and north by Vancouver Island and Alaska. It is terminated to the east by the Coast Plutonic Complex and to the west by the large Queen Charlotte Fault that separates the North American Plate from the Pacific Plate. To date, 18 exploration wells have been drilled in the QCB, with 8 offshore in the Hecate Strait and 10 on Graham Island. These wells, combined with the regional geo-

physical seismic studies and land-based geology, are the basis of the prospectivity projections. Estimates are based on abundant reservoir strata, presence of potential source rocks, numerous structural traps, and common occurrence of oil and gas shows.

The QCB and the Queen Charlotte Islands are thought to have substantial petroleum accumulations. Estimates of the oil in place average around 400 million cubic metres or 2.5 billion barrels (BBL), and natural gas is estimated to be around 565 billion cubic metres or 20 trillion cubic feet (TCF) (Table 2-1). Based on National Energy Board figures, these potential oil and gas resources are significant on a national scale (Table 2-1), although the accuracy of these estimates would be known with certainty only after drilling.


134°
133°
132°
131°
130°
129°
128°
DIXON ENTRANCE
COAST MOUNTAINS
QUEEN
Graham Island
CHARLOTTE
HECATE
STRAIT
Moresby Island
ISLANDS
PACIFIC PLATE
QCF
T.J.
QUEEN
CHARLOTTE
SOUND
VANCOUVER ISLAND
1
2
3
4
5
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7
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11
12
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15
16
17
18
LEGEND
Convergent transform
Subduction zone
Spreading ridge
Skonun Fm outcrop
Oil exploration borehole
0
100 km

Figure 2-1. Location map of Queen Charlotte Basin (Hecate Strait) showing the major tectonic features and 18 previous drillhole locations (Appendix 6).

Table 2-1. Comparison of Discovered Marketable (D/M) and Ultimate Potential Resource (UR) hydrocarbon resources of different Canadian regions (Appendix 6)

Location	**D/M Oil (10^6 m^3)**	**UR Oil (10^6 m^3)**	**D/M Natural Gas (TCF)**	**UR Natural Gas (TCF)**
Queen Charlotte Basin	400*?	730*?	20*?	26*?
A. Canada	4,555	9,177	198	733
B. WCSB	2957	3,623	159	335
C. Frontier	528	4,255	33	303
D. BC conventional	129	184	20	50

*? *Speculative estimation; WCSB Western Canada Sedimentary Basin*

Geological Features of the Queen Charlotte Basin

The Queen Charlotte Basin is expected to contain 80% of the region's total petroleum resource volume and nine of the ten largest fields. Geographically speaking, the most prospective areas are southern Hecate Strait and Queen Charlotte Sound, followed by eastern Graham Island, northern Hecate Strait and Dixon Entrance (Figure 2-1). High potential for southern Hecate Strait is based on abundant Neogene reservoir strata, numerous large structural features, and the presence of Neogene and Jurassic source rocks. Outside the basin margins, western Graham Island and adjacent shelf areas have some potential targets, but very little petroleum potential is expected overall in the onshore/inter-island areas of the southern Queen Charlotte Islands and adjacent Pacific continental shelf.

Over 50 oil, tar, or natural **gas seeps** have been identified onshore in the Queen Charlotte Islands. These seeps are widespread and exposed in road-cuts, quarries and beach outcrops, with bitumen and tar as the main products. Lawn Hill on the southeast coast of Graham Island contains one of the most areally extensive surface **oil seeps**, and strata in the surrounding or basin-ward areas is considered highly prospective for physical seismic studies and land-based geology, are the basis of the prospectivity projections. Estimates are based on abundant reservoir strata, presence of potential source rocks, numerous structural traps, and common occurrence of oil and gas shows.

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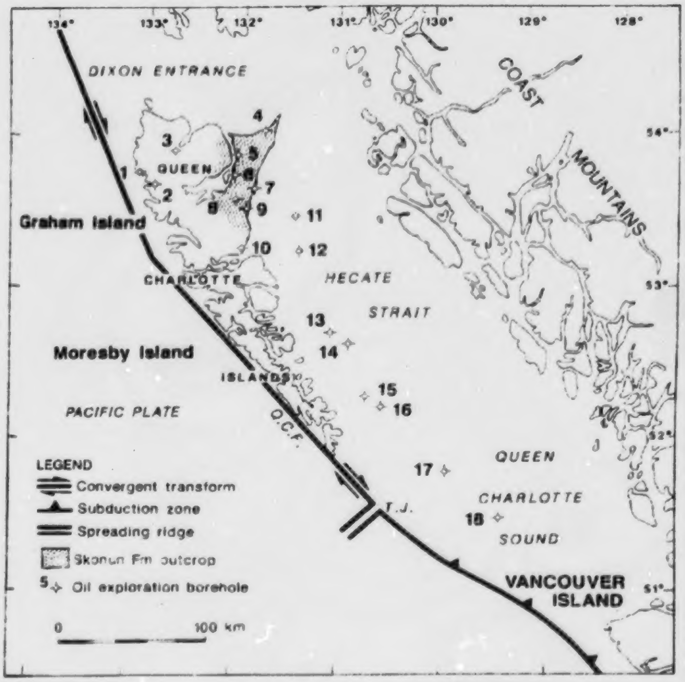
134°
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129°
128°
54°
53°
52°
51°
DIXON ENTRANCE
COAST
MOUNTAINS
QUEEN
CHARLOTTE
ISLANDS
Graham Island
Moresby Island
PACIFIC PLATE
HECATE
STRAIT
Q.C.F.
T.J.
QUEEN
CHARLOTTE
SOUND
VANCOUVER
ISLAND
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Over 50 oil, tar, or natural **gas seeps** have been identified onshore in the Queen Charlotte Islands. These seeps are widespread and exposed in road-cuts, quarries and beach outcrops, with bitumen and tar as the main products. Lawn Hill on the southeast coast of Graham Island contains one of the most areally extensive surface **oil seeps**, and strata in the surrounding or basin-ward areas is considered highly prospective for conventional oil accumulations. Shows at King Creek include oil staining, lighter oils, natural gas seeps and volatile petroleum hydrocarbons. Hydrocarbons occur from Otard Point to the head of Otard Bay, where oil films are common on streams and pools that drain this area. Subsurface shows were encountered in several wells, most notably oil staining in Neogene sandstones of the Tow Hill (onshore) and Sockeye B-10 (offshore) wells.

Shallow **gas deposits and seeps** in the Queen Charlotte Basin are distributed over most of Hecate Strait and occur in most types of surficial sediments except where glacial till is at the surface. Thick Holocene age (<10,000 years) silt deposits contain extensive amounts of biogenic gas. Gaseous sediments are also found along the base of underwater terraces, including the northern portion of the main trough and within the northern trough into Dixon Entrance. Sediments containing gas are generally near the contact of glacial till with a sand and gravel unit, and gas appears to migrate along the boundary. Gas-charged sediments are also present on the western side of Hecate Strait, and along the axis of Hecate Strait. Deep gas accumulations in Neogene strata have been identified on conventional seismic profiles in several offshore locations, several at a stratigraphic level similar to the Sockeye B-10 well show.

Faulting and Seismicity in Queen Charlotte Basin

Earthquakes from the western boundary of the Basin, the Queen Charlotte Fault, are generally of low intensity, but one as large as magnitude 8.1 has been recorded (Figure 2-2), with considerable shaking in the adjacent plate margin. A detailed analysis of the seismic pattern, at current levels of understanding, is given in Appendix 8.

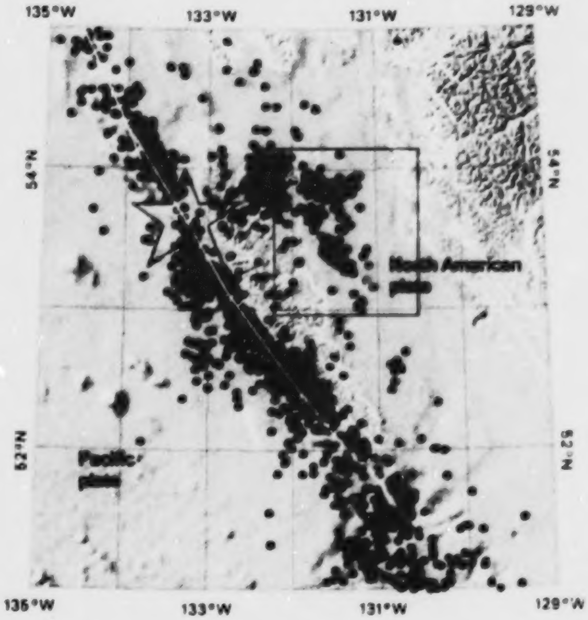

Figure 2-2. Microseismicity from Bird (1997) plotted on bathymetry; each event is shown as a single uniform-sized circle. Queen Charlotte Fault (white line) is the plate boundary between the Pacific and North American plates; the arrow indicates relative plate motion. Magnitude 8.1 event is shown as a star. (Appendix 8)

Detailed information for micro-earthquakes is best for the period of 1982 to 1996 when extra stations were placed in the region. Whether that 14-year time slice is representative of the last 100 years and can be reliably used to predict the next 10 to 50 years of earthquake activity is unknown. Geological, morphological and paleomagnetic data of the Queen Charlotte Islands have been interpreted as indicating that deformation has proceeded from south to north in the last few million years, suggesting that one could reasonably expect seismic activity to remain concentrated in the north. Much more detailed information would be required in order to assess the possibility of earthquakes occurring elsewhere in the weak and regionally stressed crust underlying the Queen Charlotte Basin.

Within the regime of any "normal" earthquake risk, the Canadian Standards Association has design standards for offshore structures, but these are currently undergoing review to be consistent with the format of the-next generation seismic hazard maps. Regulators may require more detailed seismological or geotechnical investigations to define final engineering design criteria for structures associated with offshore production (See Appendix 4).

2.1.4 Comparison of the Queen Charlotte Basin with Other Offshore Basins

Cook Inlet, Alaska

Cook Inlet, on Alaska's southern coast (Figure 2-3), has been an area of active hydrocarbon exploration and production since1957, when the first field was discovered at Swanson River. Production is from six oil fields (Trading Bay, McArthur River, Middle Ground, Granite Point, Beaver Creek, Swanson River) and three gas fields in upper Cook Inlet. Oil fields occur near the basin margin, both on-shore and offshore. Total petroleum resources (produced and remaining) in Cook Inlet are 2.2 BBBL of oil and 10 TCF of gas, the largest being the McArthur River oil field (570 MBBL) and the Kenai gas field (2.3. TCF), both of comparable magnitude to the largest fields predicted for Queen Charlotte Basin.

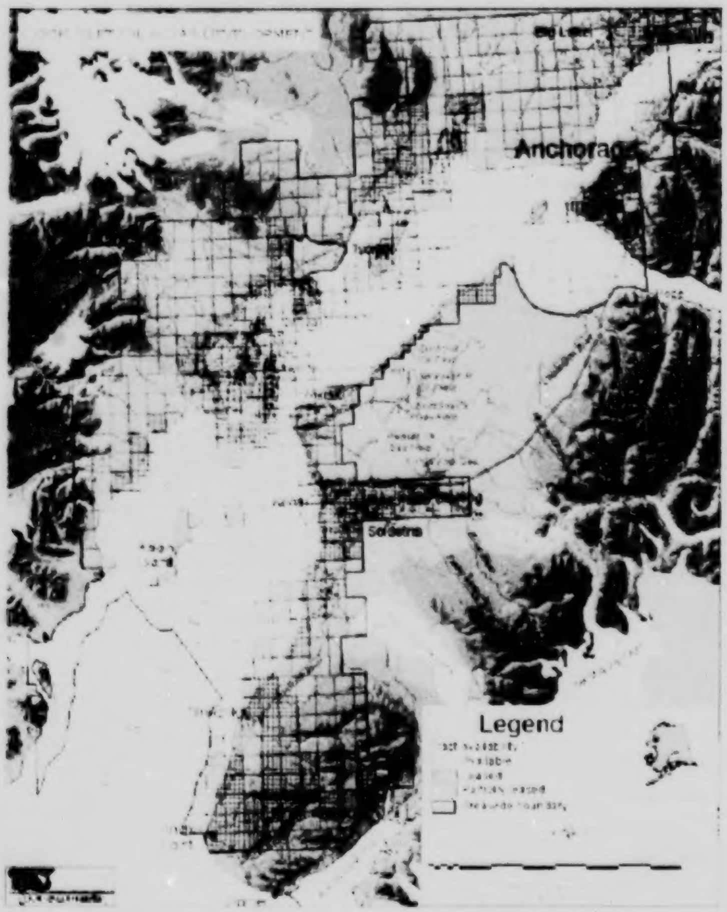

Figure 2-3. Cook Inlet, Alaska, showing the oil and gas tracts available for new leases, fully leased, or partly leased, all within the boundary outlined in red (from Cook Inlet Keeper http://www.inletkeeper.org/).

> *"Forty years of scientific studies, as well as continuous monitoring by government agencies and by the Cook Inlet Regional Citizens Advisory Council, show no adverse effects on Cook Inlet, whose waters support healthy sport and commercial fisheries. Even Greenpeace, which conducted a study near the Trading Bay Production Facility, found no evidence of industry-related contamination."*
>
> *"In short, there has been no documented evidence of any long-term degradation to the environment from more than 40 years of industry activity in Cook Inlet." Alaska Oil and Gas Association, Current Issues, 1998*
> (http://www.aoga.org/)

Despite some significant differences, (e.g. more severe winter climate, and glacial sedimentation at the head of the Inlet), Cook Inlet has more geological and environmental similarities to the QCB than any other offshore oil and gas basin. It is a large estuary running northeast from the Gulf of Alaska for about 360 km, and ranges from about 80 km wide at its mouth to an average of 25 km. Some of the most extreme tides in the world, approaching 14 metres, can generate currents exceeding seven knots. In winter, thick slabs of sea ice move with the tides and currents. It is subject to the most extreme of winter storms. Oil and gas production occurs both on and close to shore. Alongside the oil and gas exploration and production are major commercial fisheries, including five species of Pacific salmon, numerous species of bottom fish, crab, clams and shrimp. The area is known for its abundance of seabirds and sea mammals, and wilderness recreation and sports fishing abound.

The comprehensive and detailed geological / geophysical / geochemical understanding of the Cook Inlet provides a good basis for comparison with the much less studied QCB, which shares many geological similarities.

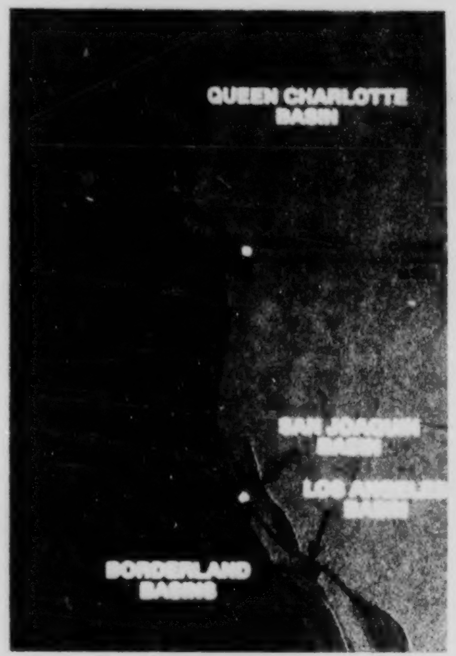

Figure 2-4. Outline of Pacific and North American plate boundaries (See Appendix 8 and 9)

California

The Southern California basins are of particular interest to this review, because their similar tectonic history and structural characteristics result in comparable seismic (earthquake) activity (see Figure 2-4).

Tectonically, both the Queen Charlotte region and California are dominated by a transform plate boundary between the Pacific and North American plates. In California the plates are moving at a relative rate of 40 km/Ma (million years), that mainly carried by the San Andreas Fault, but also by a number of secondary faults. Off British Columbia the rate is 48 km/ per million years, almost entirely carried by the Queen Charlotte Fault west of the QC Islands. In California slight compression across the plate boundary has folded and faulted the adjacent basins into structures that trap hydrocarbons. The same kinds of structures are observed in Hecate Strait.

Hundreds of scientists have been detailing California's geology and tectonics since the 1800's. Over 700 seismometers monitor every temblor; and in some areas events can be mapped with an accuracy of metres, resulting in new insights into how faults behave. In contrast the Queen Charlotte region has only six permanent seismograph stations; and the depth distribution of earthquakes on the Queen Charlotte Fault is entirely unknown. Stations lie east of the Fault and do not provide a good geometry to determine focal depths.

California has a long and rich history of utilizing and producing oil and gas (Figure 2-6). The first commercial well began production in 1876. Since then production has varied, reaching a peak in 1985 at 423.9 million barrels of oil. Oil wells tend to be in southern California and purely gas wells in northern California. In 2000 there were 46,799 oil wells and 1,169 gas wells producing hydrocarbons from 288 fields; and total production was 307.4 million barrels of oil and 379.1 billion cubic feet of gas. Altogether 1,412 offshore wells accounted for 17.6% of the total oil production and are largely found off southern California in a seismically active region.

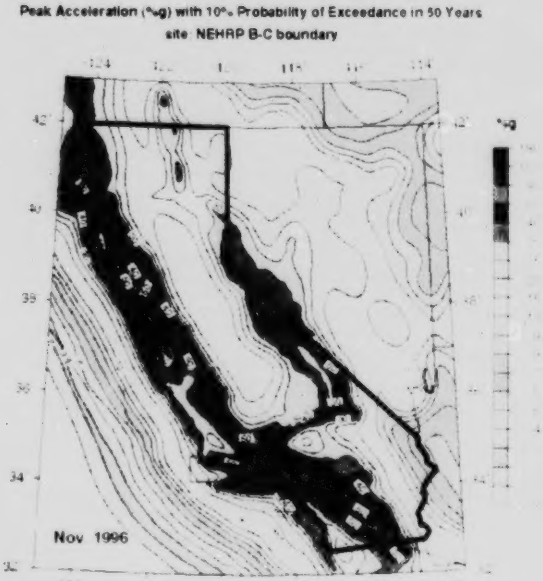
Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
-124
42
40
38
34
%g
Nov 1996

Figure 2-5. Hazard map for California and Nevada. Most of California's offshore oil production occurs in high-risk areas (Appendix 9).

Damaging earthquakes have also been a part of California's history, killing hundreds of people and causing hundreds of millions of dollars of damage. In available accounts of damage caused by major earthquakes, damage to wells and ensuing oil spills is not mentioned, and an official from California's Division of Oil, Gas and Geothermal Resources, which regulates drilling and production of wells, could recall no instance of damage done to offshore production facilities by an earthquake. An earthquake near Coalinga (Figure 2-6) (M=6.7, 1983) caused minor damage to storage tanks, which were stressed by sloshing fluids. In any event these tanks are surrounded by berms to protect against the more imminent danger of leakage from corrosion. However, nearby houses and commercial buildings of unreinforced adobe and concrete were heavily damaged, leaving 1,000 people homeless.

Spills from blow-outs were not unusual in the early days of drilling, but the last major blow-out offshore occurred in 1969 off Santa Barbara in federally regulated land. The state placed a temporary moratorium on drilling offshore until stricter regulations were in place to prevent another such occurrence. Since that time exploration and production have been highly regulated but active at a modest level.

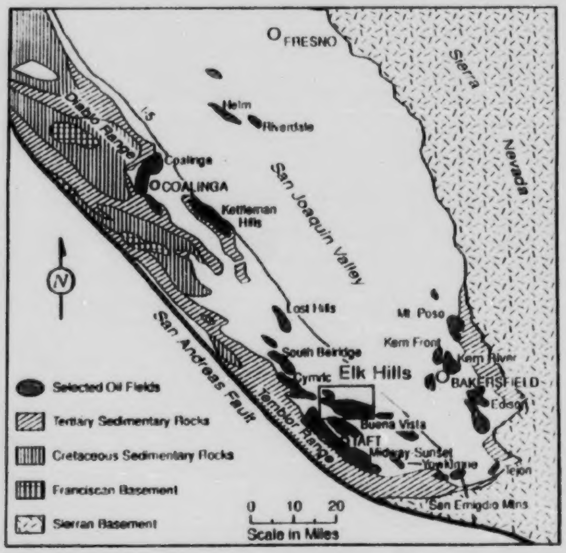
FRESNO
Sierra
Nevada
Helm
Riverdale
Diablo Range
I-5
Coalinga
COALINGA
Kettleman Hills
San Joaquin Valley
N
Lost Hills
Mt Poso
Kern Front
Kern River
South Belridge
Cymric
Elk Hills
BAKERSFIELD
Edison
San Andreas Fault
Temblor Range
Buena Vista
TAFT
Midway-Sunset
Yowlumne
Tejon
San Emigdio Mtns
Selected Oil Fields
Tertiary Sedimentary Rocks
Cretaceous Sedimentary Rocks
Franciscan Basement
Sierran Basement
0 10 20
Scale in Miles

Figure 2-6. Outline of San Joaquin sedimentary basin highlighting selected oil fields (from Reid and Wilson, 1990). Note that many are within 20 miles of the San Andreas Fault. 38,733 wells within this entire region produced 217.3 million barrels of oil or 71% of California's oil in 2000. (Appendix 9)

Other Canadian Offshore Basins

No direct geological analogies can be drawn between the Queen Charlotte Basin and other Canadian oil provinces. In ranking median recoverable resource estimates, the Queen Charlotte Basin with 2.6 BBBL of oil and 20 TCF of gas has a gas endowment comparable to the Scotian Shelf (18 TCF) and oil reserves of about half those in the Jeanne D'Arc Basin (4.7 BBBL). The Jeanne D'Arc Basin also contains an estimated 13 TCF of gas. All these basins are overshadowed by a potential 7 BBBL of oil and 68 TCF of gas projected for Beaufort-MacKenzie Basin in the Canadian Arctic.

2.1.5 Natural Gas Hydrates

Natural gases such as methane, ethane, and propane typically occur as a gas phase. However under special conditions these gases can combine with water to form a solid "gas hydrate", (or "clathrate"). These gas hydrates represent a tremendous reserve of natural gas, especially methane, globally estimated to be 6 x 10^5 TCF, twice that contained in conventional reservoirs.

Deep-sea gas hydrates off the west coast of Vancouver Island have been studied by seismic techniques and by the International Ocean Drilling Program (ODP) boreholes. They occur in a 30 km-wide band beneath much of the continental slope, and are thought generally to represent mixtures of pure methane and seawater.

If the estimated hydrate concentration at the ODP site is taken as representative of the areas of the Vancouver Island continental slope, where there is a strong bottom seismic reflector over an area of 30 km by 200 km, the total gas is about 350 TCF. This would be a 200-year supply for Canada at the present rate of natural gas consumption, although it is unlikely that the economic or technical parameters will be right for exploitation of these resources in the immediate future.

Nevertheless, it is important to understand the occurrence and characteristics of such deposits because, as explained in Appendix 10, they:

can pose geotechnical concerns, such as large-scale submarine slumping;

can cause difficulties during drilling operation due the possibility of over-pressured gases beneath the gas hydrate stability zone; and

can be a major factor in greenhouse gas storage and climate change.

2.1.6 Overview of Geologic Hazards to Offshore Petroleum Development[1]

In the current context, geologic hazards are those conditions or active processes that pose a potential threat to petroleum exploration or development activities, or to the longer term security of sea-floor production installations (e.g., wellheads, pipelines). In many instances these hazards are interrelated (e.g., earthquakes and slope stability) and in others can be related to oceanographic conditions (waves and currents, and sediment mobility). Appendix 11 presents a detailed review of the important geologic hazards that exist in various areas on the exposed continental shelf off British Columbia. These include: bedrock outcrops; Holocene faults and associated seismicity; boulder beds; sediment mobility (large bedforms in high wave and current regions); mass wasting (underwater landslides); steep slopes; shallow gas; and dynamic coastal processes. This is provided within a scenario of offshore development and production with associated pipelines, which traverse the shelf to an unspecified coastal site.

2.2 Initiatives in Coastal Oceanography

Understanding the oceanographic environment is critical at all stages of offshore operations, from exploration to production, both for the safety of operations and for the protection of the natural environment. The field of oceanography is broad and deep, and is marked today by a number of excellent international, national and BC initiatives, which will serve to strengthen our ability to monitor and manage offshore and coastal zone activities. A brief review of just a few will serve to illustrate the point.

2.2.1 International – GESAMP

The Joint **Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)** was established in 1967 by a number of United Nations Agencies. Its purpose was to provide advice to the agencies and, through them, to their member governments on a problem that was just beginning to be recognized as a major threat.

In a synopsis of current problems facing the world's oceans and the progress made in addressing them, the report of the 28th GESAMP session notes that, despite some localized successes, degradation of the oceans continues on a global scale. Persistent problems include pollution by sewage (especially pathogens), chemicals and nutrients, as well as unrestrained coastal development and over-exploitation of marine resources. On the other hand, concerted action at national and international levels has reduced the quantities of oil discharged from ships and there is convincing evidence that in certain areas better management of land-based activities has led to cleaner beaches and bathing water and seafood that is safer to eat. The report further concludes that: "Although oil is a highly visible pollutant and when spilled in large quantities can cause severe local effects, it is not regarded as a significant pollutant on global scales." Nevertheless, accurate information on trends with respect to specific qualities and conditions in different sea areas is difficult to obtain, and a Global Ocean Observing System (GOOS) has been proposed to redress this lack of data and its implementation is being planned by UNESCO-IOC, UNEP and WMO. There are component modules on the Health of the Oceans (HOTO) and on the coasts.

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[1] See appendix 11.

2.2.2 Bilateral – NEPTUNE (North-East Pacific Time-series Undersea Networked Experiments) and VENUS (Victoria Experimental Network Under the Sea)

NEPTUNE is a US/Canada initiative to create the world's first large-scale, long-term deep-water observatory. It will deploy a network of instruments linked by optical fibers and a power grid on the Juan de Fuca tectonic plate off the coasts of British Columbia, Washington and Oregon (Figure 2-7).

NEPTUNE will consist of a network of around 30 unmanned sea-floor observatories (Figure 2-10) linked to shore by submarine fibre optic cables and electrical power (50-150 kw). The network will be an invaluable tool for scientific research and education, as well as fertile ground for industrial innovation. It will provide:

30 years of multidisciplinary observations of a scientifically significant ocean area, including the sea-floor, with the time and space resolution needed to describe major processes;

"community" data in near-real-time for science and education; and

an ability to add new sensors or experiments.

NEPTUNE observations will contribute significantly to the understanding of practical issues such as earthquake hazards and the impacts of climate change on fisheries and on gas hydrates along the continental margins.

Part of the proposed Canadian side of the initiative (NEPTUNE Canada) will be a small observatory network in the Strait of Georgia and the Juan de Fuca Strait, installed before the main NEPTUNE system. This will be called "VENUS", (Victoria Experimental Network Under the Sea). These protected and accessible coastal areas will be used as testing grounds for NEPTUNE systems and equipment. Also, observations collected in the process will contribute to the understanding of exchanges between coastal basins and the open ocean, and the acquisition of real-time information on fluxes of pollutants and nutrients.

Figure 2-7. Earthquake activity offshore BC and Washington State based on observations from land-based seismic networks. The cross section at bottom shows the geological features of the Juan de Fuca plate (from US NEPTUNE site http://www.neptune.washington.edu).

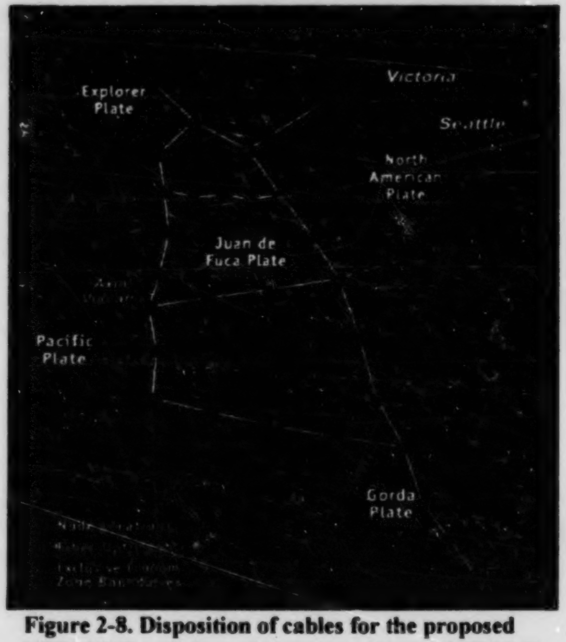

Figure 2-8. Disposition of cables for the proposed NEPTUNE real-time observatory (from NEPTUNE Canada http://www.neptunecanada.com).

2.2.3 National - Canadian Geospatial Data Infrastructure Project

A "geospatial data infrastructure" can be said to encompass all of the data sources, systems, network linkages, standards and institutional policies required to deliver geospatial data and information from many different sources to the widest possible group of potential users

Agencies around the world cooperate in the implementation of an internationally designed technological and policy framework to facilitate access to geospatial data and information. In Canada, government and industry are collaborating in the development of a Canadian Geospatial Data Infrastructure through a national program called GeoConnections. As partners in this initiative, key agencies with an interest in the marine and fresh water areas are leading the development and implementation of a Marine Geospatial Data Infrastructure (MGDI), funded as a $60 million initiative in 1999 by the federal government under the leadership of Natural Resources Canada. The purpose of the MGDI Initiative is to acquire, manage and disseminate marine data and information to all users in a timely and cost-effective manner. It will provide an information infrastructure, encourage common data and information protocols, and facilitate third party access under controlled conditions.

2.2.4 Provincial - British Columbia Marine Ecological Classification (BCMEC) and Coastal Resources Information Management System (CRIMS) (Appendix 12)

The Province of British Columbia is responsible for the management of about 30,000 km. of shoreline and sea-bed in the inshore and near-shore waters, and works with other levels of government on the management of resources under federal and local jurisdiction. BC has developed a number of coastal resource programs in support of initiatives to address economic development and diversification problems, coastal threats, land and resource conflicts, and First Nations issues, so as to support informed decision-making. Many of those programs are managed by Decision Support Services (DSS) of the Ministry of Sustainable Resource Management.

BC has been collecting some coastal resource data in a systematic and synoptic manner since 1979, using peer-reviewed provincial Resource Inventory Committee Standards, which include standards for data management and analysis. Types of environmental resource information collected include oceanographic, physiographic, and biological data, as well as anthropogenic data on fisheries, traditional knowledge, coastal tenures and land uses, and recreation and tourism use and capability. Coastal resource information is stored in the Coastal Resource Information Management System (CRIMS), which currently consists of several integrated technologies, including GIS and image-processing software, digital video, an attribute-data-management system and a trajectory model for oil spills. These different technologies have been integrated into a single system that is accessed through a custom-designed user interface.

2.2.5 Coasts Under Stress Project (CUS)

Coasts Under Stress is a five-year project that started in April 2000. Funding of $6.2 million has been provided by the Social Sciences and Humanities Research Council of Canada (SSHRC) and the Natural Science and Engineering Research Council of Canada (NSERC), with additional funding from participating universities and partners in government, business, non-governmental organizations and First Nation groups.

The natural sciences relevant to BC coastal regions will be investigated along with the human dimensions in this project, involving three universities and more than 70 researchers in natural sciences, health, social sciences and humanities. The CUS goal is to identify important ways in which changes in society and the environment in coastal British Columbia and coastal Newfoundland and Labrador have affected, or will affect, the health of people, their communities and the environment over the long run.

This program is likely to be of valuable assistance at all stages of offshore activities, and will be exceedingly important with regard to the downstream issues should a decision be made to lift the moratorium.

2.3 Comparison of Physical Conditions around Hecate Strait with those of Eastern Canada Offshore Basins

Although somewhat protected from the Pacific Ocean by the Queen Charlotte Islands, the Hecate Strait is susceptible to severe weather conditions, due to its size (less than 100 km across), its morphology, and its oceanographic characteristics. The Dixon Entrance to the north and Queen Charlotte Sound to the south have oceanographic and weather conditions somewhat different from the Hecate Strait, but all bear comparison to those of eastern Canada offshore operations (Appendix 14).

Most of the waters of Hecate Strait, Queen Charlotte Sound, and the Dixon Entrance are between 400m to 200m deep, with the exception of the 35 m Learmonth Bank at the mouth of the Dixon Entrance. These depths are common for offshore petroleum exploration and development, and thus do not present any technological or seasonal restrictions. For comparison with the east coast Jeanne d'Arc Basin (Figure 1-4), the discovery well Chevron *et al.*, Hibernia P-15 was drilled from May 27,1979 to January 2, 1980 to a total depth of 4407m in 80m water depth. In the same Jeanne d'Arc Basin, the discovery well Husky/Bow Valley *et al.* Whiterose N-was drilled between 22 June 27, 1984 to January 4, 1985) to 4628m in 122m water depth.

The climate of the Hecate Strait can be characterized as temperate, with a strong westerly onflow of moist marine air. It is one of the areas of Canada with the strongest winds, reaching 200 km/hr, driven by seasonally changing surface ocean temperatures and barometric pressure systems. Temperatures are mild, with only about 20 frost days annually in the region. Although the freezing and icing associated with this is recognized as a particular hazard of operations, it does not pose any unusual conditions in comparison to those encountered in similar higher latitude onshore and offshore exploration and production operations elsewhere in BC, Canada and internationally. For example in the Jeanne d'Arc Basin temperature variations are larger and more severe over more than half of the year. There the air temperature ranges from –17.3°C to 26.5°C, the surface water temperature ranges from –1.7°C to 15.4°C, and the thickness of icing (glaze and rime) can be 72 mm (10 year maximum) to 169 mm (100 year maximum), with spray icing thickness in the region of 316 mm (10 year maximum) and 514 mm (100 year maximum). Furthermore, there are considerable iceberg sightings in the Jeanne d'Arc Basin area of operations (annual mean: 72, maximum: 169 on a one-degree grid).

The two barometric pressure systems are the North Pacific High and the Aleutian Low. The former dominates in the summer and generates northerly winds (ca. 30 km/h). The Aleutian Low is dominant in the winter months and creates southerly winds (ca. 50 km/h). Winds are strongest from October to February and are usually out of the south or southeast. In comparison, the winds in the Jeanne d'Arc Basin have one-hour maxima of 120 to 157 km/h and one-minute maxima of 139 to 167 km/h.

Wave heights in the Jeanne d'Arc Basin, which has experienced substantial exploration and production activities, are very similar to the Hecate Strait. In the Jeanne d'Arc Basin the significant wave height is 11 to 14 m (1 to 10 year report), and a 100-year value of 17.5m. The corresponding maximum wave heights are 20.9 to 30.4m (1 to 10 year) and 30.4m (100-year).

Tidal range of the QCB is much higher than in the Jeanne d'Arc Basin, and typical surface current speeds of 25 to 50 cm/s (equivalent to 0.5 to 1 knot) are faster than those of the Jeanne d'Arc Basin (7.5 to 8.0 cm/s).

A series of current moorings are deployed by the federal government in the region, and together with IOS drifter studies, the surface currents are well studied in the prospective petroleum exploration regions of Hecate Strait and the Queen Charlotte Sound. However, more site-specific bottom current studies would be required to support any specific decisions on offshore exploration.

Regionally, the QCB water temperatures can vary from 8 to 16°C in the summer to 4 to 9°C in the winter, with most of the range in the surface waters that vary from 6 to 16°C. These relatively mild and constant water temperatures strongly moderate the regional climate. In contrast, in the Jeanne d'Arc Basin the temperature variations are larger and much more severe, with air temperatures ranging from –17.3°C to 26.5°C, the surface water temperature from –1.7°C to 15.4°C, and the sea bottom temperature from –1.7°C to 3.0°C.

CHAPTER THREE MARINE ECOLOGY

3.1 The State of the Oceans

It is well-established that our oceans have been deteriorating for many decades and continue to do so despite the numerous actions focused on reversing the negative trends. Throughout most of the 20th century the proliferation of human activities at sea, and especially in coastal waters, have had adverse effects on the marine environment. The services that the ocean provides to the biosphere, such as regulating atmospheric gas and nutrient cycling, are being compromised. At the same time, increasing demands are being placed on the world's oceans to provide food, resources and services for an expanding human population.

Although the crisis of the ocean is well-established, it is not yet widely understood on the part of the general public, nor sufficiently accepted as a priority concern on the part of many governments despite numerous efforts to meet the challenge at global and regional levels. At a recent UNESCO-sponsored conference in Paris, held in December 2001, it was noted that "we are in a critical situation of declining trends … worldwide", and that unless oceans and coasts are given a higher priority by the world community, the outlook leaves little room for optimism.

In order to appreciate the ecological features of British Columbia's coastal and offshore resources, and the possible impacts of offshore hydrocarbon-related activity on them, it is necessary to understand the complex interconnected marine ecosystem and its food webs, and to grasp the goals of conservation, maintenance of biodiversity and ecosystem integrity in complex systems involving the dynamics of other resource networks and human communities.

3.2 Government Responsibilities

3.2.1 International obligations and responsibilities

As a signatory to the international Convention on Biological Diversity, Canada recognizes "the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere". Further, Canada recognizes "that the fundamental requirement for the conservation of biological diversity is the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings", and "the close and traditional dependence of many indigenous and local communities embodying traditional lifestyles on biological resources, and the desirability of sharing equitably benefits arising from the use of traditional knowledge, innovations and practices relevant to the conservation of biological diversity and the sustainable use of its components".

This instrument provides an international framework for an ecosystem-based approach that calls for protection of marine habitats and resources at regional and national levels. All signatories to this Convention have agreed to a significant shift from a sectoral to an ecosystem-based approach of management that recognizes precaution and linkages among physical and biological characteristics of marine ecosystems and human activities.

3.2.2 Federal government responsibilities

Oceans Act (Appendix 17)
The Oceans Management Strategy section (II) of Canada's Oceans Act, which came into force in January 1997, outlines a new approach to managing oceans and their resources. This section of the Act contains provisions for the Minister of Fisheries and Oceans to lead the development and implementation of a national strategy for oceans based on the principles of:

sustainable development (development that meets the needs of the present without compromising the ability of future generations to meet their own needs);

integrated management of activities in estuaries, coastal and marine waters; and

the precautionary approach (a commitment to err on the side of caution)

This section of the Act also provides the Minister with some basic authorities and management tools to be used within the context of "integrated management plans". They include among others:

the establishment of Marine Protected Areas (MPAs); and

the establishment and enforcement of Marine Environmental Quality guidelines, criteria and standards designed to conserve and protect ecosystem health

Further, it states that, on the recommendation of the Minister, the Governor-in-Council may make regulations

(a) designating Marine Protected Areas; and
(b) prescribing measures that may include, but not be limited to,:
    (i) the zoning of Marine Protected Areas; and
    (ii) the prohibition of classes of activities within MPAs

Fisheries Act

Through this Act, Fisheries and Oceans Canada has a legislative mandate for the conservation and protection of fish and fish habitat supporting Canadian fisheries (commercial, recreational and Aboriginal), where "fish habitat" refers to:

> *spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes*

This Act prohibits the harmful alteration, disruption or destruction of fish habitat (HADD) unless authorized by the Minister.

Environment Canada has the responsibility of administering the pollution prevention sections of the Fisheries Act (sections 34 - 42), which prohibit the deposition of deleterious substances into water frequented by fish, unless authorized by the Minister.

3.2.3 Provincial government responsibilities

The provincial government responsibilities for oceans and coasts include management of the shoreline and the seabed in the inshore and nearshore waters.

3.3 Knowledge about Marine Ecosystems

3.3.1 Limits to knowledge of the oceans and capacity to monitor changes

Overall, we know relatively little about our oceans, the largest and most biologically diverse environment on our planet, particularly with respect to the role and vulnerability of the resources and habitats. So that the human population can pursue opportunities for economic development in the coasts and oceans, and at the same time protect their ecological integrity and biodiversity, there is an urgent need to

obtain detailed scientific information about the physical and biological aspects of marine ecosystems;

build greater capacity to manage and regulate access to resources; and

strengthen science-based monitoring and assessment to identify marine ecosystem changes and the impacts of human use of ocean services and resources.

To address concerns about the importance of using an integrated approach in the management of ocean resources globally, there has been a switch in recent years from sectoral-based, single-species management systems to systems that take a more holistic, ecosystem approach. It is also now recognized globally that a system of marine protected areas is an essential component for ocean management and for the overall understanding of marine ecosystems and protection of their biodiversity.

3.3.2 Knowledge gaps about marine ecosystems

There are extensive gaps in our knowledge about marine ecosystems, especially when compared with terrestrial ecosystems. With many unanswered questions with respect to their structure and function, we need more complete knowledge in order to understand their complexity and how the removal of resources and disturbance of habitat will affect them. Examples of areas where more information is needed for effective management using an ecosystem approach include:

- the relationship between the physical environment (for example, mixing attributes and flushing rates, sediment properties, and other aspects of the habitat) and the dependent biological environment;
- marine microorganisms, plankton, the benthos and the algae that are the foundation of the ecosystem, feeding those higher up on the food chain (see Appendix 15);
- the relationship between the overall ecosystem productivity and biological diversity, especially in determining the impact of removal or altering the productivity of single species;
- the precise spawning times and areas for all species and the seasonal and vertical distribution of eggs and larvae;
- the amount of habitat required to support a viable population of a certain species and the feeding and reproduction requirements of a population or species;
- the effects of habitat disruption on species interactions and survivorship;
- the role of deep-sea animals in global cycles of nutrients, carbon and contaminants; and
- the role of nearshore areas as migration corridors, rearing, feeding and staging areas for many species.

With this background in mind, a cautious approach must be employed when considering any future development of the resources of the ocean.

3.3.3 Assessment and monitoring of marine ecosystems

As marine ecosystems are considered for resource development, there is a need for rigorous, meaningful and long-term environmental monitoring. As part of the responsibilities of the federal and provincial governments described above, it is critical to obtain, assemble and analyze baseline information that is already available about the structure and function of the ecosystem and to monitor natural or human-induced changes in these values over time, in order to identify areas for which data are insufficient or non-existent. What is needed is a complete set of detailed physical oceanographic and biological information for each marine ecosystem. There are a number of initiatives addressing this need already in place, or under development, at the international, national, regional and local levels. Some of these are described below.

International

The Global Ocean Observing System (GOOS) is a unified, permanent, global public service for data and information exchange about the oceans and seas designed to meet the needs of the world community of users of the oceanic environment. It is a coordinated system for gathering data about the oceans and seas and it promotes integration of the coastal environmental research community and its linkage to the community at large. It will develop and implement an international strategy for the acquisition, gathering, and exchange of these data, and will provide descriptions of the present state of the oceans, including living resources.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is discussed in Chapter 2. Its role is to cover all scientific aspects of the prevention, reduction, and control of marine environment degradation, and within that framework it provides evidence that the best way to conserve marine diversity is to conserve habitat in the coastal area.

Federal

The new federal initiative, the Seabed Resource Mapping Program (SeaMap; http://seamap.bio.ns.ca) is led by the federal departments of Natural Resources, National Defence, and Fisheries and Oceans. The focus of SeaMap, which is still in its early planning stages, is sea and lake-bed mapping of Canada's offshore, coastal and aquatic lands. This information will assist in decision-making with respect to ocean resource use. The applications cover a broad range, from telecommunications to offshore exploration; national security to environmental assessment; and fish habitat assessment to sustainable development.

Regional

A newly proposed initiative for monitoring regions of the Pacific Ocean, the North East Pacific Time-series Undersea Networked Experiments (NEPTUNE) is described in Chapter 2. This project will result in a large-scale ocean observatory system interconnected by fibre-optic cable which will, for the first time, provide intensive and comprehensive observations of the deep-sea ecosystem at a number of sites, over a long period of time. This information will allow us to assess long-term and cumulative changes in marine, particularly deep-sea, ecosystems brought about by natural occurrences and human activities and will be in place long enough to monitor the potential recovery of any damaged systems.

Provincial

Through the Decision Support Services Division, the British Columbia Ministry of Sustainable Resource Management manages and coordinates the B.C. coastal inventory and analysis programmes. The various programmes, which are focused on obtaining information about marine ecosystems and marine conservation and protection, are briefly described below.

The CRIS (Coastal Resource Information System) is a comprehensive GIS-based inventory system. It was originally designed for oil-spill response and countermeasures, but also provides data and analyses for coastal and marine planning, conservation, protection and management applications (see Chapters 2 and 4)

The BC Marine Ecological Classification is a hierarchial marine classification consisting of four nested divisions based on physical properties, and a fifth division based on current, depth, relief, substrate, salinity, slope, temperature, stratification, and wave exposure. This fifth division, termed "ecounits", is the first example of a large-scale (1:250,000) classification applied over a large area. The ecounits were developed for the application to coastal management and marine protected areas planning. Currently, there are no data available for the offshore out to Canada's 200nm EEZ boundary of BC or for the north coast fjords.

A preliminary list of Valued Marine Environmental Features (VMEFs), which are key features of the marine environment valued for their conservation, recreational and cultural-heritage characteristics, has been compiled, including, for example, kelp beds.

An initiative is also in place to develop a methodology to identify Marine Sensitive Areas (MSAs), where an MSA is defined as

> "an area containing habitats, biotic communities or species important to the ecological function of the local, regional or global environment that is also vulnerable to human disturbance"

and habitats are defined as

> "areas occupied by species that are particularly susceptible to human disturbances or areas occupied by species which would experience difficulty recovering to viable or manageable levels if disturbed. ... For example, habitats such as marshes, estuaries, wetlands, and eelgrass beds are formed by the interaction of complex physical processes and have very slow recovery rates if these physical processes are disrupted or disturbed."

The goal of this programme is to use systematic intertidal, subtidal and offshore inventories to delineate sensitive and vulnerable habitats.

3.3.4 Difficulties associated with monitoring change in marine ecosystems

The difficulty with any set of information on marine ecosystems lies in determining whether or not it is representative of the "natural" state of the ecosystem, and assessing whether or not observed changes are the result of human activities or natural occurrences. Because of the natural spatial and temporal variability of both physical and biological characteristics in marine ecosystems, it is essential that information be collected over the long term.

3.3.5 Monitoring cumulative effects

Similarly, it is difficult to assess the potential effects of one type of human activity on a marine ecosystem, because the data are frequently confounded by the effects of other human activities. It is generally agreed that we do not currently have the capacity or all of the knowledge to undertake meaningful environmental effects monitoring at the ecosystem level over the long term, especially with respect to cumulative effects of a variety of stresses.

It is important that the cumulative effects of all activities be evaluated, as much as is possible, on an ecosystem scale; that is, encompassing the effects of multiple activities on multiple species at multiple ecological levels. Clearly, this is far more complex than measuring the effects of just one single variable on an ecosystem: for example, the measurements of temporary seismic noise relative to background noise from frequent vessel traffic in a marine area.

With the commitments and initiatives described above, we are gaining a better understanding of what is required to undertake this type of monitoring. Without adequate information available, prudence, caution and conservatism must continue to be the watchwords for any management of marine resources and habitats.

3.4 Protected Areas

3.4.1 Marine Protected Areas

For several years, Fisheries and Oceans Canada, Environment Canada and Parks Canada have been working together with the government of British Columbia on a Pacific Marine Protected Areas Strategy. The goal is to take a coordinated, collaborative approach towards the development of Marine Protected Areas (MPAs) on the Pacific coast. This Strategy was released for public distribution in August 1998, but the province has not yet officially signed.

Fisheries and Oceans Canada takes an ecosystem approach to the establishment of MPAs, whereby the entire ecosystem will benefit. At the time of the Oceans Act, four areas of the Pacific were identified for MPAs, two nearshore and two offshore. The locations for the nearshore MPAs have been identified; and one of these, Race Rocks, is nearing completion as an official MPA. The offshore locations have not yet been identified. Subsection 35 (3) of the Oceans Act allows the federal Minister of Fisheries and Oceans to prescribe measures or prohibit activities that may interfere with marine ecosystem integrity.

The British Columbia government has also identified a number of MPAs for BC. A provincial MPA is any area of tidal water together with associated natural and cultural features in the water column, within, or on top of the seabed which has been designated by the Protected Areas of British Columbia Act or under the Park Act, Ecological Reserve Act or the Environmental and Land Use Act. The primary tools used to evaluate provincial MPAs include CRIS, VMEFs, and the BCMEC (see above). A list of the more than 100 provincial MPAs identified to date is available at: http://srm.www.gov.bc.ca/dss

3.4.2 Marine Conservation Areas

Bill C10, which is now in the Senate and very likely to pass this year, will allow for the development of Marine Conservation Areas. Parks Canada has identified a number of eco-regions for Canada, each of which has a unique collection of physical and biological characteristics. Five eco-regions have been identified on the west coast of Canada. The proposed Gwaii Haanas Marine Conservation Area covers two of these eco-regions. This will be the only Marine Conservation Area in northern BC. One other Marine Conservation Area will be established in coastal BC. Exploration and development of hydrocarbons will be prohibited in Marine Conservation Areas.

3.5 Queen Charlotte Basin

3.5.1 An overview

For any marine ecosystem, the structural and functional elements are defined by a diverse array of organisms, together with the physical characteristics of the water and the coastal and seabed areas. In comparison to most of the earth's marine ecosystems, the Queen Charlotte Basin, which has not been subjected to urbanization or significant industrialization, would be expected to be in good condition. A description of the boundaries for the Queen Charlotte Basin, and of the physical factors which determine the types of organisms that will reside there and 'make a living' or pass through it, are included in Chapter 2.

Each marine ecosystem is unique and very complex, with numerous interactions between and within a diverse group of living organisms and the physical environment. The 1986 Report of the West Coast Offshore Assessment Panel describes this complexity and diversity in Queen Charlotte Sound:

> "Nearshore ecosystems occur near rocky shores, on mud flats, in estuaries and in shallow bays. Sunlight penetrates throughout nearshore ecosytems and nutrients flowing through them from the sea are supplemented by those from the land. In shallow bays, estuaries and mudflats, nutrients regenerated from decaying organic matter are important to productivity. Water movement distributes some of the nearshore production into deeper water in the form of drifting detritus and rafts of seaweed, which contributes to pelagic and benthic foodwebs. In turn, the larvae and juveniles of fish such as salmon and herring depend on this production for survival.
>
> "Continental shelf ecosystems exist where deeper water prevents sufficient light from penetrating far enough for plants to grow on the seabottom but where the water is shallow enough so that production in the surface waters is directly accessible to the benthic community. The animals in benthic and pelagic communities interact directly. For example, sandlance migrate to shallow waters diurnally to feed on plankton, thereby transferring organic matter to the benthic community. Such shelf seas are also shallow enough so that currents and winds can mix the waters to make nutrients available to all parts of the foodweb.
>
> "In contrast to the nearshore ecosystems where seaweeds and seagrasses are primary producers, phytoplankton are the primary producers in continental shelf ecosystems. The growing season for phytoplankton in Queen Charlotte Sound and Hecate Strait is from April or May through to October.
>
> Both nearshore and continental shelf ecosystems have grazers and scavengers. Grazers such as zooplankton, snails, clams, chitons, and urchins consume phytoplankton and seaweeds. Grazers, in turn, are eaten by starfish, predacious snails, salmon, herring, seabirds and gray whales. Some of these are eaten by halibut, ling cod, cormorants, eagles, falcons, seals, dolphins and killer whales.

> Scavengers exist on the remains and excretions of other organisms. Typical of these are bacteria, sea cucumbers, anemones, and shore crabs."

The wetlands that are also part of the Queen Charlotte Basin are most important for their function as nursery and rearing areas, and for stabilizing coastlines and providing protection against storm surges. They filter out nutrients from land run-off and are areas where fine sediments rich in organic matter accumulate, making them a highly productive component of the ecosystem that is critical to its biodiversity and fisheries.

On the western limits of the Queen Charlotte Basin, there are regions deeper than 1000 metres, the deep-sea, and the physical and biological characteristics of this part of the ocean are the least understood. In fact, it is only in the past year that we have known about the existence of unique sponge reefs in the deeper regions of Hecate Strait. Most deep-sea communities depend for their food on events at the surface. Very little is known about how deep-sea communities respond to natural events and human disturbances or resource extraction.

3.5.2 What do we know about the structure and function of the Queen Charlotte Basin marine ecosystem?

The Queen Charlotte Basin is a dynamic and diverse ecosystem that is highly productive, with resident and transient species. It also supports numerous aboriginal, commercial and recreational fisheries and tourism. It is currently in very good condition relative to many of the globe's marine ecosystems.

A description of our current knowledge with respect to the location and physical attributes of the Queen Charlotte Basin is provided in Chapter 2. With respect to the biological components of the ecosystem, there is considerable information about the number of species and types of habitat, but our knowledge of the biology and life cycles of most of these species, and of the role of each in the ecosystem overall, is very limited.

To provide a snapshot of the diversity of species (overall species numbers estimated to be between 500 and 1,000) that exists in this marine ecosystem, examples of numbers for just a few of the species of fauna are described in the Table 3-1 below:

Table 3-1. Queen Charlotte Basin Ecosystem Diversity

Organism	Number of species and (or) stocks
Salmon	6 (many stocks and more than 5,000 populations)
Herring	1 (five stocks in QCB)
Groundfish	more than 70
Shrimp	7
Crab	5
Sea Urchins	5
Seabirds	15 species which breed on the coast
Marine Mammals	29
Octopus	9

There may also be species as yet undiscovered (such as, until recently, the deep-water sponges in Hecate Strait, or the species of giant squid discovered in the Gulf of Mexico) in 2001, or not normally abundant in the area.

A comprehensive description of the biological components of the Queen Charlotte Basin is presented in Appendix 15 and additional information is found in the JWEL report. Some key points are described below.

Salmon

The 1986 Offshore Exploration Environmental Assessment Panel Report states:

> " About 650 rivers and streams in the region are used for spawning by juveniles. Large runs of salmon occur in the Bella Coola River, Skeena River, Nass River, Smith Inlet, Rivers Inlet and elsewhere. Also, salmon stocks from Alaska, Washington, Oregon, and California migrate through the region's waters to and from the Gulf of Alaska and the north Pacific. Immature salmon may spend several months feeding in estuaries while gradually becoming adjusted to salt water before moving offshore. More than 1 billion fry are believed to migrate up the coast. "

Salmon subsequently become a key species contributing to the fertility of forest ecosystems through their use as food for bears, eagles and other species.

In the JWEL Report's sections on salmon (3.1.2) and salmon fisheries (3.2.1, 3.4.2) there are several incorrect or misleading statements. The productivity for salmon stocks tends to cycle over long periods (e.g., ten years or more) in relation to "ocean regime shifts". These decadal scale shifts have only recently been recognized. During the past five years on the Pacific coast, we have been experiencing a downward trend in marine survival associated with an ocean regime shift. However, this is now turning around and we expect that salmon stocks will be much more productive in the next few years as a result of the increased marine survival produced by the regime shift. New information provides new perspectives on environmental change that will affect the salmon stocks and overall ecosystem structure and function in the Queen Charlotte Basin.

The statement "However, the 1999 wild salmon harvest was the lowest in 50 years, and has resulted in concerns over conservation", although true, is misleading. In fact, a major contributor to reductions in the harvest were the significant conservation measures that were put in place by the Department of Fisheries and Oceans in 1998, specifically to protect certain coho salmon stocks. The statement, "decline in the salmon industry is being mitigated largely through aquaculture in BC " is again misleading. Aquaculture might temporarily make up in commercial terms for a decreased wild salmon catch, but it cannot mitigate the decline in the wild salmon industry. Salmon aquaculture and the wild salmon fishery are separate industries. In fact, a network of scientists, First Nations people, non-governmental organizations, and others, currently working with DFO in the development of a wild salmon policy, are concerned that the effects of aquaculture of primarily an "exotic" species (Atlantic salmon, *Salmo salar*) will endanger the future of the six wild Pacific salmon (*Oncorhynchus*) species.

Marine Mammals

The JWEL report reviews the species of marine mammals found on the coast of British Columbia. The species that reside in, or migrate through, the Queen Charlotte Basin include gray, sei, humpback, minke, finn, sperm and killer whales, dolphins, and seals, including the Northern elephant seal, which breeds in California and resides in the north in the summer. Overall, we understand very little about the biology, habitat and ecological roles of these species. Most of our information is on killer whales, harbour seals, and Steller sea lions, and yet it is by no means complete.

Almost all individual killer whales (*Orcinus orca*) on the British Columbia and Alaska coasts have been identified and catalogued on the basis of natural markings and fin shape. Records of their seasonal movements, diet, social structure and life-history are available. Very recent studies have expanded our understanding of killer whale populations. There are now thought to be two non-associating populations of whales, known as residents and transients. Transients differ in travel patterns, dive intervals and group sizes; and they feed on different prey (residents, fish; transients, marine mammals). There are five populations of killer whales on the coast: two residents (north and south), two transients (north and south), and one offshore population.

In November 2001 the southern resident population, which has declined by 20% in the past six years, was listed as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). An endangered species is one that is facing imminent extirpation or extinction. The northern resident and southern and northern transient populations were designated by COSEWIC as "threatened". Threatened species are likely to become endangered, if limiting factors are not reversed. Both northern resident and transient killer whales are found in Queen Charlotte Basin. The offshore population was listed as "of special concern".

Seabirds

Appendix 16 reviews what is currently known about seabirds of the waters of Western Canada, identifies knowledge gaps, and offers suggestions about how to complete the current picture on seabirds in this unique and diverse habitat to form a solid, updated and internationally compatible baseline of information.

3.5.4 Ecological niche

Each species in the marine ecosystem has its own ecological "niche" or way of life. Each niche is unique, and each species is a member of a community, sharing the resources and contributing to overall ecosystem function. Something that apparently affects only one species may, therefore, ultimately affect the whole ecosystem. Examples of ecological niche are described in Table 3-2 and 3-3 below.

Table 3-2. The Ecological Niche of the Spot Prawn, *Pandalus platyceros*

Habitat	**Rocky or hard substrate in depths from the intertidal to 487m**
Spawns	Late fall or early winter
Larvae	Planktonic stage of up to three months. Diurnal, moving from depths during day and towards surface at night
Feeding pattern	Bottom foragers
Moult	Spring and early summer
Predators	Larval stage: many larger species including fish, marine mammals and seabirds Adult stage: many species including pelagic and benthic fish, marine mammals, and birds

Table 3-3. The Ecological Niche of the Pacific Herring, *Clupea pallasi*

Habitat	Juveniles Inshore, Nearshore Adults Pelagic
Spawns	March to April
Spawning location	Inshore protected waters; eggs are deposited on kelp, red algae, eelgrass and rockweed
Hatching	Eggs hatch after 10 to 20 days. After hatching, larvae found in large masses near the spawning grounds.
Feeding pattern	Larvae small planktonic organisms Juveniles larger planktonic organisms Adults large plankton, larval fishes
Predators	At least 40 other species including seabirds, seals, sea lions, whales and salmon and groundfish

3.5.5 Issues related to the Queen Charlotte Basin marine ecosystem

Importance of understanding life cycles and species interactions

The complexity of the life history of a variety of both invertebrate and vertebrate species demonstrates the importance of the life cycle and the changes that occur in the cycle of each species, together with associated different uses of the ecosystem. It is because of this great diversity of organisms, and life cycle stages, that much of the Queen Charlotte Basin marine ecosystem is used almost year-round, as spawning and rearing habitat.

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Table 3-3. The Ecological Niche of the Pacific Herring, *Clupea pallasii*

Habitat	Juveniles Adults	Inshore, Nearshore Pelagic
Spawns	March to April	
Spawning location	Inshore protected waters; eggs are deposited on kelp, red algae, eelgrass and rockweed	
Hatching	Eggs hatch after 10 to 20 days. After hatching, larvae found in large masses near the spawning grounds.	
Feeding pattern	Larvae Juveniles Adults	small planktonic organisms larger planktonic organisms large plankton, larval fishes
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The interactions between species are very important to the overall function of the ecosystem with some species (the keystone species) playing a more critical role. Any factor that has a negative impact on the keystone species would be expected to have profound impacts on the entire ecosystem.

For example, sea mussels form densely aggregated beds from the upper intertidal to subtidal depths. They provide a protective matrix for a very complex community of more than 300 different species. They are long-lived, and species richness increases with increasing mussel bed age and thickness. However, as filter feeders, mussels are very sensitive to oil contamination and are known to readily accumulate Polycyclic Aromatic Hydrocarbons (PAHs) in areas of urban run-off and oil spills.

Consequently, the exposure of sea mussels to oil as the result of frequent small or catastrophic large spills would have serious implications for the entire food web, including fish, sea-birds and marine mammals.

3.5.6 Economic value of the current fisheries

In addition to providing traditional food for the First Nations peoples that reside in this area, this rich and diverse ecosystem provides significant economic benefit through commercial fisheries, which can be sustainable if managed appropriately. For example, the estimated annual landed value of one species of prawn, the spot prawn, from north coast waters ranges from $1.2 - $4.3 million and for the Queen Charlotte Islands, approximately $1 million. For red urchins, the largest of the five sea urchin species, the estimated value of the total annual catch from 1995 to 1999 for northern waters ranged from approximately $6 - $10 million. The estimated annual landed value for groundfish is very high: for example, the total landed value of groundfish for British Columbia (a significant portion of which was caught in the north) in 2000 was $133.7 million, with a wholesale value of $186.5 million. In the past six years the annual value of sablefish and halibut, most of which was landed on the north coast, ranged from $24 - $32 million and $30 - $40 million, respectively. It is important to note that prices quoted here reflect a period where there has been a downturn in the market and a decrease in the currency of the major buyers. So these values could be substantially higher in the future.

3.5.7 Current stresses on the Queen Charlotte Basin ecosystem

There are a number of human activities that currently affect the Queen Charlotte Basin ecosystem, including: commercial fisheries for numerous invertebrate and vertebrate species; recreational fisheries (primarily salmon); shipping; and tourism. In addition, it is anticipated that in the future this region will be the location for significant shellfish foreshore harvesting, and shellfish and finfish aquaculture activity. Further, there are natural stresses such as the decreased productivity related to the recent ocean regime shift as well as anticipated stresses associated with climate change. A possible new stress would be caused by exploration and development of other resource industries such as oil and gas.

In summary, it is very difficult to measure the cumulative effects of natural occurrences and human activities on marine ecosystems. However, it is critical to understand that these stresses, many of which are insidious, can threaten the health and even the viability of the marine ecosystem over the long term.

3.6 Oil and Gas Industry - Potential Stresses

Generally, any effects attributed to the oil and gas industry will depend on the unique factors of the ecosystem and must be viewed over the long term.

There are two categories of impacts that the oil and gas industry would have on the Queen Charlotte Basin marine ecosystem:

impacts associated with exploration, development and production; and
impacts associated with catastrophic spills from blowouts or product transport.

3.6.1 Impacts associated with oil and gas exploration, development and production

Produced Water and Drilling Muds

Theoretically, it is possible to use technology whereby produced water and drill cuttings are re-injected and drilling muds are recycled, resulting in near zero emissions (Chapter 4). However, to our knowledge there is no site where this is currently the standard practice. The JWEL report discusses evidence for impacts of produced water and drilling muds on surrounding habitat and biota, and acute effects are thought to be generally minimal, particularly with the use of the less toxic synthetic-based fluids. However, recent reports of heavy metal contamination indicate that discharged drilling muds can have significantly adverse impact on the biota in areas in the immediate vicinity of drill rigs, and may even be incorporated into the food chain. On the other hand, a body of knowledge obtained in recent years from field studies conducted in Atlantic Canada, the North Sea, Gulf of Mexico, and California using indicator species as well as larval and juvenile fish and some zooplankton species, suggests that discharges pose little risk to the biota and habitat. These uncertainties still need to be addressed, especially with respect to site-specific and localized effects on larval and planktonic communities and to long-term chronic effects on all species and the ecosystem in general.

Small Oil Spills

Frequent small oil spills are known to be associated with all phases of offshore oil and gas operations. Many of these spills originate from the transfer of diesel fuel from supply vessels to the rig. The spills would be expected to have direct effects on the biota, especially on the larval and juvenile fishes that frequent the water column, which are known to be particularly vulnerable to oil. For example, the larvae of many fish species must ascend to the surface to swallow the seed bubble of air that initiates the development of the swim bladder. Even a very thin film of oil on the surface could interfere with this process at the 'swim up' stage and thus result in undeveloped swim bladders, arrested development and greater mortality of larval fishes.

The cumulative effects of these small spills over time, particularly when coupled with effects of other stresses, could seriously damage components of the marine ecosystem. For example, there is some evidence that chronic, low-level pollution from shipping operations may have negative effects on seabird populations. We need to determine what levels of risk are acceptable for the small oil releases associated with offshore development, and to understand that in the broader context of such spills from regular shipping, tourism, commercial fishing, and other activities.

Flares and Lights

A brief review is provided in Appendix 16.

Noise and Seismic Activity

There is a general consensus that hearing is probably the primary sense of whales, dolphins, and a number of other marine species. Most marine mammals depend on sound as they hunt for food, detect predators, find mates and keep their herds together. There are already concerns with regard to "noise pollution" in the oceans, originating especially from the propellers of super tankers and cargo ships, and the effects it may be having on global marine ecosystems over the long term. The velocity of sound in water is four times greater than in air, and the transmission loss in water is much lower due to lower attenuation. Therefore, depending on local conditions, sound waves may travel long distances under water, and detection ranges can exceed 100km. Underwater noise can potentially mask marine mammal underwater communication and perception of natural sounds.

A variety of constant noises is associated with the operation of drill rigs during all phases: for example, depending on the rig, there will be continual noise from equipment such as compressors, pumps, generators, and gas turbines in addition to the noise from aircraft and supply vessels. Noise in the air could have effects on birds and pinniped haulout areas. Recent reports from Russia show that the operational noise associated with rigs during production is affecting the migratory behaviour of gray whales.

The greatest impact from the exploration and development phases, however, is associated with seismic activity. A review of the effects of seismic activity on marine ecosystems is provided in Appendix 15 and the JWEL report.

Seismic Noise and Marine Mammals

Hecate Strait and Queen Charlotte Sound are sufficiently confined by land on both sides that there is a concentration of migratory and non-migratory fish, mammals, birds and other biota in the nearshore zone. Although very little information exists about the role of hearing and listening in the overall "way of life" for many of these organisms, it is thought that a number of species that travel in the nearshore area are 'listening' as they migrate. Transient killer whales, in particular, travel or forage in this area, without echolocating, suggesting that passive listening provides cues for prey detection and orientation. Additional noise could possibly mask these auditory cues, increasing the likelihood of stranding or collision with the bottom, or reduced effectiveness in feeding, communication or migration.

Whales have been observed to swim away from seismic noise. However, their normal activity may be disrupted for long periods and functions such as surfacing and respiration or feeding can be affected, thus inducing stress. Of greatest concern is evidence of physical and physiological damage to hearing, and the consequent hearing loss, of mammals from intense sound sources such as sonar and airguns used for seismic surveys. This effect can have serious consequences: for example, in March 2000, shortly after the US Navy conducted exercises in the Bahamas, 17 whales from four different species beached themselves over a four-day period. Seven of the whales died; and a number of them were found to have haemorrhages of varying degree in their hearing organs.

Seismic Noise and Fish

Adult fish respond by swimming away to avoid the seismic zone. A fish may react to a seismic array more than 30 km away, and intense avoidance behaviour can be expected within 1 – 5 km. This type of noise may affect the role of the swim bladder and lead to haemorrhaging and even mortality of adult fish. There is evidence of short-term disruption of fish density in areas of seismic testing and this may affect fisheries in those areas. However, it should be noted that fisheries and the oil and gas industry have been co-existing in the North Sea and in Cook Inlet, Alaska over a long period of time.

Seismic Noise and Early Life Stages of Fish and Invertebrates

Seismic activity would be expected to affect organisms that are unable to move away from the vicinity, such as plankton, eggs, and larval and juvenile life stages of fish and invertebrates. Probably of most concern with respect to impacts is the potential effect on the vulnerable larval or juvenile stages of fish, and future recruitment, although information is lacking on this subject. For example, in particular it would be expected to interfere with swim bladder development. Any adverse effects on these early life cycle stages could be crucial for the Queen Charlotte Basin region, as much of it is used as nursery grounds or rearing areas throughout the year.

The serious threat that seismic activity poses for some species of the marine ecosystem makes it critical to obtain as much information as possible about:

the acoustic sensitivities of whales and other marine mammals;

the effects of seismic activity on adult, juvenile and larval fishes and invertebrates and plankton; and

the cumulative, chronic and population-level impacts of noise on marine life

Ballast water

Deballasting of oil rigs and associated vessels could theoretically add to the spread of invasive species such as the predacious European green crab, a species introduced to San Francisco Bay by way of ship's ballast water several years ago. This organism has now migrated to the south coast waters of British Columbia, where it threatens the future of indigenous crab species.

3.6.2 Impacts of major oil spills

Each oil spill event and its environmental impacts are unique. Many conditions affect oil impacts, often in complex, cumulative or synergistic ways that are still not well understood. A thorough description of oil impacts on individual species typically associated with the Queen Charlotte Basin ecosystem has recently been published by Parks Canada (www.dsp-psd.pwgsc.gc.ca/Collection/R61-2-8-11E.pdf). There are also specific references to oil impacts on organisms in the JWEL report and Appendix15.

The numerous studies following the *Exxon Valdez* oil spill in 1989 have made a major contribution to our knowledge regarding the impacts of oil on marine ecosystems. We now, for the first time, have extensive information with respect to the long-term effects of oil spills on several species.

One of the key factors determining the extent of the impact of an oil spill is the type of habitat. Effects on pelagic (open water) and deeper subtidal benthos species are relatively small, whereas effects at interfaces can be significant, for species such as seabirds and marine mammals that contact the sea surface. Similar large effects are seen in intertidal ecosystems at the land-sea interface. Pelagic species, which complete part of their life cycle at interfaces by having floating eggs at the sea surface or by spawning intertidally, are also particularly vulnerable.

Fish readily accumulate oil into their tissues, through ingestion as well as by absorption through the body surfaces. Depending on the species, they can detoxify some oil through metabolism, but the process of detoxification can be stressful and interfere with other functions. A typical response to stress in many vertebrates is increased susceptibility to disease, as well as interference with reproduction and growth.

Our understanding of the oil impacts on eggs and larval and juvenile fishes is incomplete, but it is thought that these stages are particularly vulnerable to oil. Encounters with oil could lead to arrested development and poor recruitment or even mortality. However, the natural fluctuations in fish recruitment are so great that even in well-studied fisheries, oil-induced mortalities of juvenile and pre-recruitment fish of less than an order of magnitude would be unlikely to be detectable.

Contamination by oil, leading to loss of fish habitat and food sources, and the persistence of oil residues in fine sediment and sheltered habitats such as estuaries and streams, could have long-term effects on nursery and rearing habitat.

Marine mammals

Marine mammals show no avoidance of areas contaminated by oil spills and therefore would be expected to be at risk. Most of the mortalities observed with oil spills have been for fur-bearing mammals, such as harbour seals, sea otters and seal pups. Because they depend on their fur for insulation, these animals are thought to have the most difficulty with oil.

The presence of oil has not been proven to cause mortality in whales. Unlike furred animals, they do not have a thermal problem when oiled, because they rely on blubber for insulation. There is evidence that the presence of oil reduces the filtration efficiency of baleen whales, but these effects are reversed in the short term. However, any mammals that are dependent for food on bottom-dwelling species (such as invertebrates that are known to accumulate hydrocarbons) may exhibit sub-lethal or long-term effects in response to oil spills.

Our understanding of the linkage between tissue hydrocarbon levels and oil-related tissue damage and health status in marine mammals is incomplete. Also, because of our incomplete understanding of the natural cycles of many species, it is difficult to separate out effects of natural cycles from effects of oil spills. For example, the decline of the sea otter populations of Alaska's Aleutian Islands, which was observed prior to the EVOS event, is known to be the result of reductions in available prey; whereas the decline of the Prince William Sound sea otter populations has been attributed directly to the EVOS event.

Seabirds
The effects of oil, both short-term and long-term, on seabirds are discussed in Appendix16. Similarly to other species, specific effects, vulnerability, and ability to recover will vary, based on life history and natural history characteristics. These would include, for example, differences in habitat use, energetics or life history strategy. Nearshore species would be the most vulnerable. Large variability in seabird numbers and breeding success due to natural factors is a common natural event, making detection of the degree of oil effects difficult (Appendix 16).

However, with the long-term studies following the *Exxon Valdez* oil spill event, there is new information demonstrating that a number of bird populations, including loons, harlequin ducks and pigeon guillemots, have not fully recovered from the effects of the oil nine years after the spill. As is the case with other species, the long-term effects of chronic low-level pollution are now being recognized as a significant threat to bird populations, and they may possibly be more damaging from a population-level perspective than the one-time mortality associated with a major spill.

Invertebrates
Generally, oil contamination affects invertebrates more than finfish species. The effects range from mortality to flesh tainting, reproductive disruption and compromised immunity, which may last for months. Bioaccumulation of oil compounds has been demonstrated in rapidly growing organisms. Most important are the indirect effects where the mortality of important species at the bottom of the food chain, or the consumption of contaminated invertebrate species, may disrupt the food web and possibly disrupt overall ecosystem function. For example, sea urchins and sea mussels, which are food for numerous invertebrate and vertebrate species, are known to be highly sensitive to oil. Severe impacts on these species could have significant consequences for the ecosystem's diverse community, and recovery could take many years to happen.

Long-term effects
The visible effects of an oil spill permit a quick assessment of damage to the immediate physical environment, but the long-term effects on flora, fauna and the affected area (including contiguous habitat) are more subtle, and difficult to measure and evaluate. The most recent publications on the effects of the *Exxon Valdez* spill by the scientists at the Alaska Fisheries Science Centre Auke Bay Laboratory demonstrated long-term impacts that have altered our perception of the impacts of oil spills. Their results show that oil persists in certain habitats for extended periods of time, such as in the intertidal reaches of salmon streams, in soft sediments underlying mussel beds, and on cobble beaches with large boulders. Thus, a major point-source pollution problem has evolved over time to a non-point-source event with long-term persistence and impacts. The highest concentrations of oil in beach sediments in the early years following the *Exxon Valdez* spill were found in soft sediments underlying mussel beds. The resulting contamination of the mussels by PAHs indicated that the underlying oil was biologically available and thus posed a risk to the other species of the food web, such as fish, birds and marine mammals.

These Alaskan scientists have also demonstrated that the same event resulted in significant damage to pink salmon abundance in the early years following the spill, caused both by reduced survival of embryos in oiled stream deltas and reduced growth of fry in contaminated marine waters in the year of the spill. Recent experiments have provided evidence that leaching of PAHs into the water still continues in some streams, indicating continued exposure of salmon eggs, more than 10 years after the spill. Similar experiments with herring embryos in saltwater noted increased mortality at low concentrations of weathered oil, suggesting that the results are not unique to pink salmon or fresh water.

3.6.3 Knowledge gaps about effects of oil spills

Some lessons from the Exxon Valdez oil spill
One lesson is that pre-perturbation baseline data are absolutely critical for understanding what resources are at risk from oil and gas development, as well as for evaluating the population and community-level consequences that may result following development. Furthermore, there is a problem with relying on data from short-duration studies conducted under laboratory conditions, as the field conditions for each spill are dif-

ferent, and the unnatural spatial and temporal scales in laboratory studies cannot account for natural variations. Also, most studies involve single species and do not address the integrated or ecosystem nature of the impacts. Our ability to differentiate between natural ecosystem changes and oil pollution effects is not well-developed. We need to know much more about natural ecosystem changes. Moreover, our understanding of long-term chronic sub-lethal impacts of oil pollution, which may show up generations later, is incomplete. Finally, obtaining accurate measurements of recovery in oil-damaged ecosystems is proving to be just as difficult as obtaining meaningful data on the effects of the original damage.

3.7 Conclusions

A rich and diverse ecosystem such as the Queen Charlotte Basin presents a number of options for sustainable economic benefit, including fisheries, tourism and possibly oil and gas development. The nature of ecosystem structure and function means that serious disturbance to habitat, or any of the biological features, by any of these options, could possibly cause damage to the overall ecosystem, and there is also the possibility that this damage would be irreversible. If this should happen as the result of oil and gas development, then the options with regard to other benefits, such as from fisheries and tourism, will be reduced.

Before any new industry is initiated in a specific marine ecosystem such as the Queen Charlotte Basin, it is critical to establish a complete set of pre-perturbation baseline data on the biota, including life-cycle history, and their habitats, so that we can understand and assess which aspects of the marine ecosystem are at risk from the proposed development and evaluate the population and community-level consequences that may result following development.

CHAPTER FOUR ENGINEERING AND TECHNOLOGY

The JWEL report constitutes a good general review of the significant engineering literature related to the economic, safety and environmental concerns of exploration and development activities for the offshore oil and gas industry. Recent technological advances and operational procedures relevant to British Columbia offshore areas were described, as were the qualitative risks associated with all phases of exploration and development. The five sequential phases in typical offshore oil and gas developments were characterized as follows: seismic and geophysical surveys; exploration; development; production; and decommissioning. Some observations will be made about most of these phases, many of which have been discussed by the Environmental Assessment Panel in 1986 and the authors of the COFRI and JWEL reports.

4.1 Seismic and Geophysical Surveys

The 1986 Panel proposed that airgun seismic surveying be limited in time, space and intensity, and that the initial surveys on the West Coast serve as experimental opportunities to develop the knowledge to assess the likely impacts of further work. The need to use explosives to shoot "tie-ins" has been eliminated by the development of airguns capable of working in shallow water. Recent geophysical exploration routinely uses 3-D seismic surveying undertaken by vessels that carry out multiple lines at a time, using multiple airguns. It should be noted that recent advances in the acquisition, processing, and interpretation of airborne gravity and magnetics surveys now enable the use of these data for solving a wide range of seismic problems. A review of the gravity data demonstrates an accuracy approaching that of 2D marine surveys. Incorporation of high resolution gravity and magnetics into 3D seismic surveys and interpretations yield a positive impact on the final interpreted results.

The issue to be assessed is whether the greater rate of airgun firing over an intensive survey area for 3D seismic surveying results in greater impacts. Little information exists, as mentioned in Chapter 3, on the impacts on fish eggs and larvae or on salmon migration and behaviour from seismic surveying. Recently the Joint Nature Conservation Committee (JNCC) in the UK has established guidelines for reducing the impacts of seismic exploration on marine mammals. Member companies of the UK Offshore Operators Association and the International Association of Geophysical Contractors have indicated they will comply with these guidelines in all areas of the UK Continental Shelf and in some areas elsewhere. Certainly this Panel would urge application of similar guidelines to be required under license conditions to all blocks licensed off the BC coast.

4.2 Exploration

The JWEL report reviewed a number of significant advances in drilling technology that have enabled the industry to conduct offshore exploration and production in much deeper waters. It is now technically feasible to contemplate the extension of offshore operations beyond the narrow continental shelf off the coast of BC. Among the most important technological advances are the advent of horizontal multilateral drilling, the development of dynamic positioning systems, and improvements in blowout preventer (BOP) design. Exploration drilling would most likely be undertaken by a semi-submersible unit or by a drillship.

In 1986 concerns were expressed about the use of high-toxicity oil-based drilling muds and about the use of bright artificial lighting on rigs and platforms. Today, Canadian offshore regulations require the use of much less toxic synthetic-based drilling fluids. It should certainly be possible for a joint Canada-British Columbia Offshore Petroleum Board or equivalent to require the re-injection of drill cuttings and produced water. Although it is generally accepted that fish and squid are attracted to sources of bright light, the effects of light on their populations appear to be negligible. Birds can become disoriented by lights, particularly in foggy or overcast weather, but incidents of bird mortalities caused by operating lights or gas flares appear to be low. (See Appendix 16)

4.3 Development and Production

Production options include a moored semi-submersible, a tension leg platform, a Floating Production Storage and Offloading unit (an FMSO is being used to produce the Terra Nova oilfield off the coast of Newfoundland in about 90 m of water) or possibly a gravity base structure similar to some of those in the UK and Norwegian sectors of the North Sea. A typical field development concept is shown in Figure 4-1.

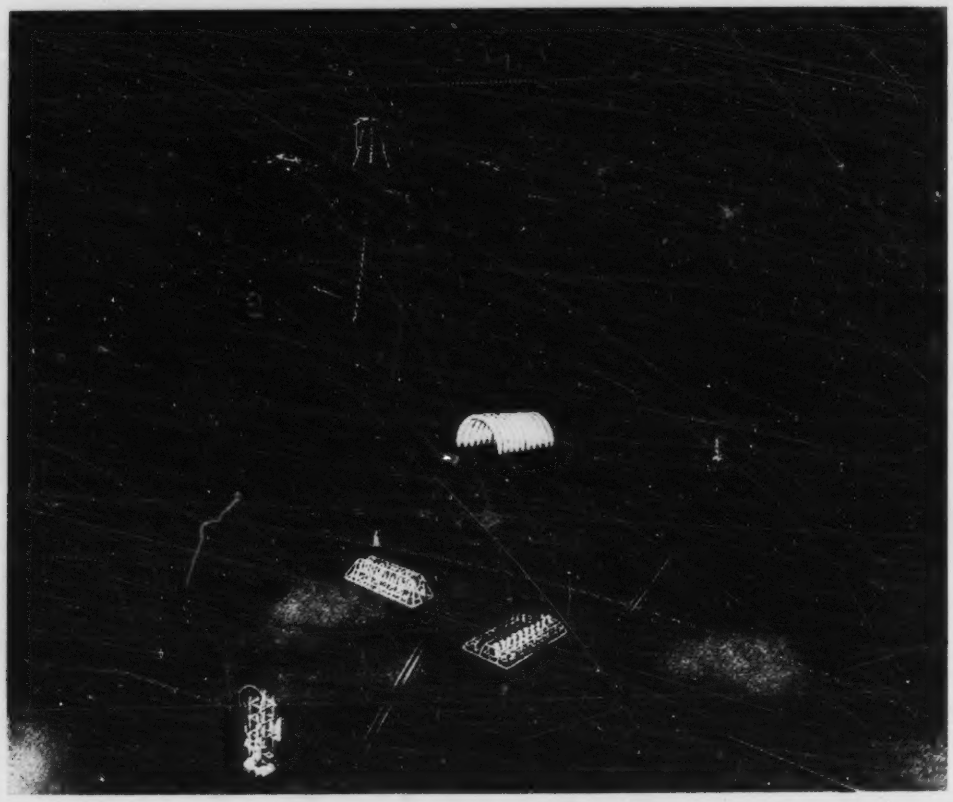

Figure 4-1. Conceptual field development scheme using a floating production system. (KME a.s promotional material).

It should be possible to require that export lines from the production platforms be tied into pipelines as opposed to offloading the oil into shuttle tankers by way of buoys. Pipeline monitoring and shut-down systems should be employed that would maintain maximum pipeline integrity and the least possible environmental risk. Suitable surveying would be required to establish the most secure pipeline route.

One way to manage carbon is to use energy more efficiently to reduce our need for a major energy and carbon source-fossil fuel combustion. Another way is to increase our use of low-carbon and carbon-free fuels and technologies. The third and newest way to manage carbon, capturing and securely storing carbon (carbon sequestration), is truly radical in a technology context. Many oil fields worldwide use injected CO_2 for enhanced oil recovery, and CO_2 sequestration is being practised in a reservoir in the Norwegian sector of the North Sea. The ocean itself represents a large potential sink for sequestration of anthropogenic CO_2. A recent report sponsored by the US Department of Energy notes that carbon sequestration holds great potential to reduce greenhouse gas accumulations to levels of acceptable impact at affordable costs.

A catastrophic explosion and fire occurred in 1998 on the Piper Alpha steel jacket production platform in the UK sector of the North Sea. A total of 167 people lost their lives and immense financial losses were suffered by the industry and the by the UK government. The central recommendation of the public enquiry under Lord Cullen was that a safety case regime be developed for offshore installations. The Health and Safety Executive set up the Offshore Safety Division to take over offshore health and safety matters from the Department of Energy. The separation of the regulatory authority for these matters from the organization that issues the exploration and production licensees is something that the government of British Columbia should investigate, as is now being recommended for the Canada-Nova Scotia Offshore Petroleum Board.

The JWEL report concluded that uncertainties in the physical environment (highly variable bathymetry, strong waves and currents, high waves, high seismic activity with the associated risks of slope failure and tsunami generation) could be dealt with through increased factors of safety in engineering designs and operational procedures. One omission in the engineering section of the JWEL report is reference to the Canadian Standards Association (CSA) Code for Offshore Structures, currently being updated. The standard was formulated so as to achieve target safety levels of $(1 - 10^{-5})$ per annum. The loads specified for earthquakes, for example, are set at annual probability exceedance of 10^{-4} per annum. The Canadian environment was very much the focus of this reliability-based standard and some background information is given in Appendix 18.

4.4 Risk of Oil Spill and Blowout

According to the JWEL report, "spills larger than 50 barrels have decreased considerably due to improved technology and higher operational standards. The risk of a blowout is highest during exploration drilling, considerably lower in the development phase, and lowest during the period of production. The only recorded blowout in Atlantic Canada occurred in 1984 and involved only 1500 barrels of condensate". However, a blowout is always a possibility with exploratory and production well drilling, and could have significant consequences for the North Coast. It should also be pointed out that existing tanker traffic within our 200 nautical mile exclusive economic zone continues to threaten the same coast. Some progress in governance has been made through the Canada Shipping Act since the Public Review Panel on Tanker Safety and Marine Spills Response Capability, chaired by David Brander-Smith, tabled their report. However, gaps in marine oil-spill response capacity exist for the Pacific coast, and Canada still allows single-hulled tankers and tank barges in its ports.

The consequences of a large oil spill are uppermost in the minds of the First Nations, and the communities bordering northern Vancouver Island, the Queen Charlotte Islands and Hecate Strait. It is now realized that oil-spill response decisions based on minimizing the cumulative damage over a ten-year period are more likely to yield the best long-term outcome for the resources and the habitat. If the potentially affected areas contain habitat capable of retaining oil for long periods of time, the best long-term outcome might be achieved by preventing the oil from coming ashore by the use of dispersants or otherwise. Although a particular dispersant may have toxic properties, dispersants also minimize the amount of oil coming ashore, causing less habitat contamination and lowering the potential for long-term damage. In such circumstances, the use of dispersants might be appropriate, despite the potential for short-term damage. Conversely, if there is little critical fish habitat within the spill trajectory, it might be prudent to leave the spill untreated.

Exploratory drilling and production create the risk of an uncontrolled release of oil from a blowout. This risk was recognized by the 1986 Panel, which described three documented incidents resulting in significant losses of oil to the marine environment. Drilling operators recognize the risk and take steps to mitigate it. It is recognized that the risk of a large loss of oil has a low, although finite, probability of occurring. However, since such incidents can occur, it seems prudent that the BC government should understand its potential liabilities in such a contingency before a decision is taken to remove the moratorium.

4.4.1 Approach

The technical approach to providing this information involves making a quantitative risk evaluation of exploratory drilling and/or production. A risk assessment of this nature has two components: (i) estimating the probability of the spill actually occurring; and (ii) determining the consequences of such an event.

The first component can be approached from two directions: one, based on the statistics of spills from similar operations under similar environmental and geological conditions in other jurisdictions; or two, using reliability analysis.

The prerequisite information and mathematical tools for the second component include:

data on the natural resources that can be damaged by oil;
data on the cultural and economic resources that can be damaged by oil;
data on the marine climate (winds, ocean currents and ocean chemistry) of the area;
an oil spill trajectory and weathering model; and
a mathematical model for evaluating natural, cultural and economic resource damages.

A number of outcomes are possible depending on the formulation of the model for evaluating damage, but a useful form was found to be the "conditional risk curve" expressing probability of damage in monetary units for a particular spill. This approach was used, for example, by Chevron in 1980-81 during a preliminary evaluation of exploratory drilling risks in Queen Charlotte Sound. Of course, in addition to the quantified risk curves, one gains valuable insight into the social and cultural consequences of an oil spill (how it affects people's everyday lives), and what components of the ecosystem are at most risk (e.g. the commercial and native food fishery).

4.4.2 Sufficiency of Knowledge

The following comments pertain to the current status of data and knowledge applied to determining the consequences of a large spill.

Natural resources

Baseline data for the North Coast have increased somewhat in the past decade, through scientific studies undertaken through federal and BC agencies. However, the reduction in the scientific capacity of these departments is alarming in view of the numerous scientific knowledge gaps identified in Chapter Three. The work undertaken by the BC government is of particular importance in this regard, specifically the creation of the Coastal Resource Information Management System (CRIMS), which makes important baseline data available in GIS format. This system is managed by Decision Support Services (DSS) of the Ministry of Sustainable Resource Management, and is used to provide data and analyses for coastal resource management, conservation, protection and planning applications. An important component of CRIMS in the oil spill context is the Biophysical Shore-zone Mapping System, which obtains and stores spatial information on physical and biological characteristics of the shoreline. Basic data collection has been completed for the North Coast. This information is currently being analyzed and entered into the database (available in mid- to late 2002). It is also understood that other spatial data sets on biological resources have been assembled for the offshore areas in CRIMS, and that recent efforts have been made to coordinate and share such data with the federal departments, as mentioned in the JWEL report. It is hoped that sufficient data, in terms of spatial coverage, relevance and quantity, will be available for a risk study as early as mid-2002.

Data on cultural and economic resources

As part of the coastal inventory and information management system developed by the BC government, data have also been collected on human uses (e.g., fisheries, traditional knowledge, coastal tenures and land uses, and recreation and tourism use and capability). Within this framework, a preliminary list of *Valued Marine Environmental Features* (VMEFs) has been drawn up, based on a multi-disciplinary literature review complemented by discussions with experts in marine sciences, recreation and cultural-heritage resources. The completeness of these data for the North Coast has not been assessed at the time of writing, but the data structures and definitions are in place that would allow for filling gaps as part of a risk evaluation. As is the case for natural resources, these data are accessible in GIS format, greatly facilitating the spatial analysis required in a risk evaluation.

Marine climate

Understanding and predicting marine climate variables have advanced greatly since 1986. These developments are reviewed in the COFRI and JWEL reports. While the new data are not necessarily in forms immediately useable for oil spill simulation, they can be converted relatively easily, and there is no impediment to a quantitative risk evaluation.

Oil spill trajectory and weathering model

Advances in oil-spill modelling in British Columbia were reviewed by COFRI in 1996. Essentially, the principles for modelling, with suitable algorithms for weathering (evaporation, emulsification and changes in density and viscosity), are understood and programmed in useful computer models. Both the BC government and Fisheries and Oceans Canada currently use the SPILLSIM model developed in Vancouver by Seaconsult Marine Research Ltd. When applying these models to the North Coast, the spatial scale of possible effects must be carefully considered. Natural, economic and cultural resources occur at relatively small scales; and an accurate risk evaluation, the spill model must provide data at suitably equivalent scales. One can gain an appreciation for the behaviour for floating oil from Figure 4-2, which shows the slick from the *Exxon Valdez* in Prince William Sound. The slick is comprised of long streamers and patches of oil, not large "pools" moving coherently across the sea. It is desirable to attempt to simulate this real behaviour of oil as far as possible. The Prince William Sound setting is appropriate for British Columbia. The highly indented shoreline of the North Coast leads to complex currents, at small scales, that will require careful derivation. Similarly, available oil spill models will probably require improvement to handle these data and deal properly with small-scale effects around islands and inlets, and the application of weathering algorithms at these fine scales.

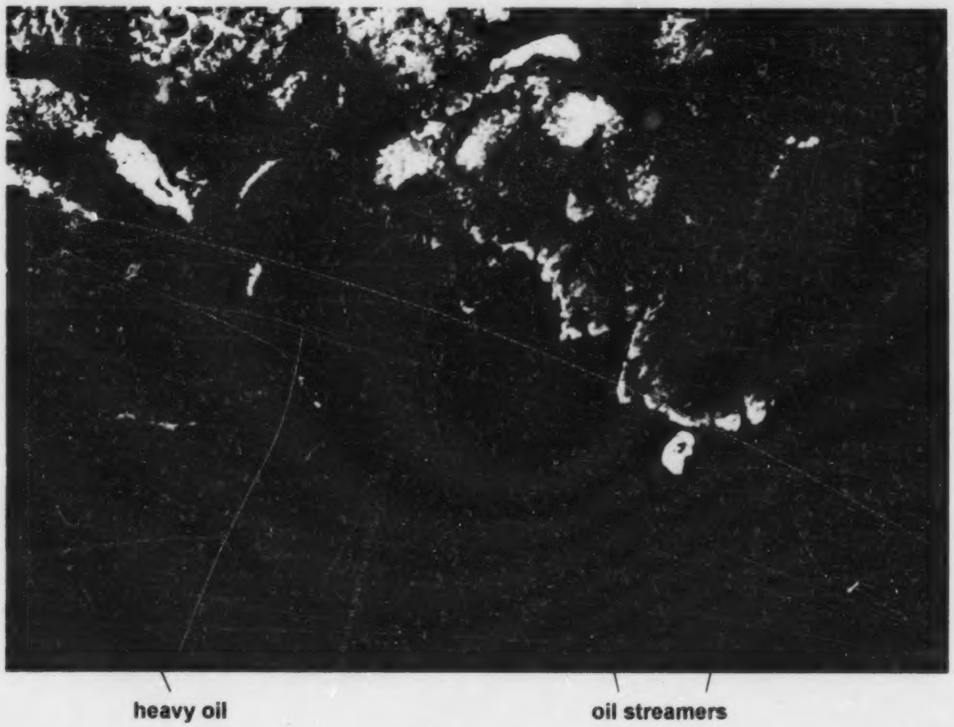

Figure 4-2 Aerial photograph of the Exxon Valdez spill in Prince William Sound, illustrating how oil spreads in streamers close to shore.

Resource damage model

In general terms the resource damage model makes an interaction of the oil with the valued resources – biological, physical, economic and cultural – to compute damage. The analysis is essentially spatial, but it accounts for variations in time as the oil moves through a particular area. Damage may result from toxicological effects on biota (e.g. loss of fish at sensitive life stages), destruction of habitat, direct and indirect costs, loss of use and enjoyment, loss of real property value, and loss of culturally important marine areas or artifacts, amongst others. Definition of the damage function is an important step in risk evaluation. It is obvious that definitions of damage contain uncertainty: uncertainty in direct cause and effect, like mortality of fish and mammals; uncertainty of long-term cumulative effects; and uncertainty in more subjective definitions such as those dealing with loss of cultural value. Uncertainty in all of these components is dealt with in a statistical manner in the resource damage model. The procedure then yields a *conditional*[2] *risk curve*, showing the probability of exceeding a particular damage level. If damage is expressed in dollars, the risk curve shows the likelihood of exceeding certain costs associated with a spill, and can include clean-up costs as well as direct damage to the environment. Simulation of different spills provides a family of risk curves for the scenarios included in the suite of runs, from those with the lowest damage to that with the greatest potential for damage. When the family of curves is related to the location of the spill, the information provides a method of ranking areas where drilling might or might not be permitted. Similarly, when applied to spills at different times of the year, the results can be used to restrict drilling in particular seasons, if there is a significantly greater risk of damage at one time of the year compared with other seasons.

4.5 Conclusion

Offshore hydrocarbon exploration and development cannot be undertaken without impacts on the environment. The subject area is a sensitive one and care is needed in any development. The objective should be to maintain risks at an acceptable level and to mitigate them. Safety has been improving in the industry and techniques and methodology are available for dealing with risks. Decisions with regard to lifting the moratorium and proceeding with development can be taken on this basis. As actual exploration and other activities take place, there is a need for quantitative risk analysis. This will provide an appropriate vehicle for decision-making in which the various stakeholders can assess the situation. Risk analysis will also assist in defining some measures to be employed in the regulatory regime. Decisions can be made, for example, on procedures for mitigation of oil spills, effluent discharges, and type of drilling fluid to be used. Existing practice and the regulatory environment in Canada are such that risks would be on the low end of the scale.

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[2] Conditional means that only the probability of damage is considered, independently of the probability of the spill occurring

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 General

It may be useful to remind British Columbians that the principal reasons for the current provincial moratorium are two-fold: jurisdictional and environmental. The question of whether the sea-bed and subsoil under the Queen Charlotte Basin and adjacent waters belong to provincial or federal jurisdiction remains unresolved. There is still a variance of opinion on the degree of environmental risk associated with ocean and coastal activities in general, and with offshore hydrocarbon activities in particular.

Other reasons have been given for keeping the moratorium in place. It has been argued that the benefits of offshore production for the local economy would be short-lived: that the introduction of an offshore industry would bring in outsiders who might cause social disruption and challenge local cultural patterns; that British Columbia, lacking the necessary infrastructure of industrial knowledge and skills, would become dependent on other economies and jurisdictions; and that, in any event, the benefits and costs for BC are uncertain, depending on the outcome of complicated and protracted negotiations with the federal government, the oil industry, and possibly other extra-provincial interests.

On the other hand, it appears that the resource may be very substantial, perhaps comparable with reserves under the continental shelf in the areas of the Northwest Atlantic. If these estimates are accurate – and this can only be determined through exploratory drilling – then an offshore industry of Northern BC could become a major revenue generator for the provincial economy. Most of the above objections, it can be argued, could be met through careful planning, through the development of a rigorous regulatory regime governing all phases before, during and after production activities, and through the negotiation of fair federal-provincial fiscal arrangements, and of revenue-sharing arrangements with the First Nations and other coastal communities.

Given the complex and sometimes controversial nature of offshore development policy, and the relative open-endedness of the third and fourth of our terms of reference, this Panel offers a number of comments on the implications that seem to flow from the stock of scientific and technical knowledge summarized in the preceding chapters. Comments are offered also on some of the concerns that should be addressed, as the BC government considers whether to revise its present moratorium policy; and on various challenges that might have to be met if offshore development were to proceed with maximum benefit to the people of British Columbia.

We structure our conclusions and recommendations below in the order of the Panel's terms of reference.

(i) the scientific and technological considerations relevant to offshore oil and gas exploration, development and production;

5.2 Energy Context

From the perspective of the offshore science and technology community there is a great deal of technical knowledge that needs to be considered in order to assess the potential role of offshore hydrocarbon production. In short, the case for or against removal of the moratorium should be evaluated in the broader context of energy policy options among various alternative sources of energy.

5.2.1 Alternative Energy Systems

In the summer of 2001 the BC Government appointed a five-member Energy Policy Task Force to develop a "comprehensive, long-term energy policy" for the province. The report and recommendations of that Task Force are to be submitted to the BC Minister of Energy and Mines by January 31, 2002. Although that will follow the date for completion of this Panel's own report on offshore science and technology, our terms of reference seem sufficiently broad to permit comment on the relationship between long-term energy priorities and the current offshore hydrocarbon moratorium, from the science-and-technology perspective.

Offshore oil and gas production – like onshore oil and gas production – belongs to the mainstream of conventional non-renewable energy production. World demand for oil and natural gas is high and rising steadily, especially on the part of the more rapidly developing countries. A great deal of technical knowledge has accumulated in the various sectors of petroleum science and technology, and operational standards, onshore and offshore, have risen impressively.

As no doubt being reviewed by the BC Energy Policy Task Force, a number of alternative sources of energy, both conventional and non-conventional, can be considered as candidates for inclusion in a sophisticated, economically feasible and environmentally sound energy strategy for the province over the next 30-40 years, a period that would coincide with the period that any offshore hydrocarbon production would be expected to last. From the science-and-technology perspective, each of these options has to be examined with a view to the research-and-development time and cost requirements that must be met before they can claim the status of solutions to the difficult problems of sustainable energy. In this Panel's view, ending of the present offshore moratorium policy would be compatible with, and could be used to reinforce, a provincial energy policy that encouraged more substantial future investments in research and development of sustainable energy systems.

The candidate sectors might include existing sources such as hydropower and nuclear power, but a longer-term global strategy should be developed so as to give a high priority to the least environmentally harmful of options, such as hydrogen and fuel cell technology, wind-wave-and-tidal power, solar energy, and ocean thermal energy conversion (OTEC). Initiatives could be designed to build upon particular BC strengths or advantages, such as hydrogen and fuel cell development, wind-wave-and tidal power projects, gas hydrates and coal-bed methane production.

Such a long-term, multi-source, energy strategy developed along these lines would be compatible with a number of research and development programs being conducted in Canada and in British Columbia specifically.

The National Research Council's Innovation Centre located on the UBC campus is engaged in efforts to develop core competencies relevant to the long-term strategic technology needs of Canadian manufacturers, with a focus in the field of hydrogen-based fuel cell technology. At present Canada has a large share of this secondary power market, but it faces severe competition from other countries, especially the United States and some European countries. In the Canadian context, BC universities are leaders in hydrogen and fuel cell research, providing a particular opportunity for British Columbia to make a major contribution to sustainable energy production at the global level by using its oil and gas reserves as a means of transition to a hydrogen-based future.

It is also believed that BC has numerous coastal locations appropriate for tidal energy extraction, using new "non-barrier" technology, apparently with small risk of environmental disturbance, for the generation of ultra-high-density electricity. At present BC Hydro is conducting a province-wide assessment of tidal current potential. It seems that the North Coast region (especially around Prince Rupert, Kitimat and Stewart), Vancouver Island (Discovery Passage, Quatsino Narrows, and Dodge Narrows), and the Vancouver region have sufficient tidal and wave volume, depth and flow characteristics to generate thousands of megawatts. Investment in tidal/wave power, which has long been operational in France for example, would help BC to meet rising energy demands, provide export revenues, and create new jobs in manufacturing, engineering and sales, and also help Canada to meet its Kyoto Protocol commitments for long-term control of greenhouse gas emissions.

Recommendation 1. **We recommend that a decision by the BC government on the immediate question of whether or not to lift the offshore moratorium should be taken with a view to its priorities in the larger context of a provincial energy policy.**

(ii) further research or studies that should be undertaken to advance the "state of knowledge" on these considerations

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5.3 Deficiencies in Knowledge and Capacity

This Panel has interviewed a number of specialists and, with the assistance of earlier reports and new ones prepared by highly qualified consultants, has reviewed the literature on offshore-related science and technology. The growth of generic knowledge in these areas over the past 15 years is impressive, and the technologies available to the petroleum and related sectors of industry have improved considerably.

However, significant gaps remain in a number of scientific and technical areas that would be of special relevance to British Columbia if the government should decide to revise the current blanket moratorium policy and signal its willingness to consider programs of offshore exploration and development. It is of similar concern that the public sector capacities to regulate the range of activities that might ensue from such a policy appear to be deficient.

The offshore and coastal regions of BC present an array of potential hazards and engineering challenges, including earthquakes, tsunamis, severe storms, high tidal ranges and currents, and other natural phenomena. However, in the year 2002 we look back on a half-century of offshore experience on the part of the petroleum industry in many countries, and here in Canada on three decades of oil and gas operations off the coasts of eastern Canada. The international and Canadian oil and gas industries are now immersed in the challenges of offshore development and production, and in the application of technology far superior to that of just a decade ago. Nevertheless, risks need to be assessed.

5.3.1 Sea-bed Conditions and Sub-surface Geology

Multi-beam swath bathymetry is the current state-of-the-art technology for determining sea-floor morphology and characterization. It provides an indication of materials present on the ocean bottom, including bedrock, sediment distribution, and, by extension and interpretation, areas of more or less risk from submarine slumping, liquefaction, turbidity currents, and related phenomena. Other techniques, such as side-scan sonar, sub-bottom profiling and sampling are routinely incorporated into the final interpretations. Surveys have been done for selected areas of the BC offshore, most locations being close to population centres that might be most at risk from related hazards such as disruption of communications or pipelines. The only currently available interpretation of possible sea-floor hazards in Queen Charlotte Basin is the Geological Survey of Canada Open File No. 2195, at a scale of 1:250,00. Some side-scan, high-resolution seismic reflection and multi-channel seismic reflection data are available in the regions of earthquake activity in the Queen Charlotte Basin. Much more reliable data and interpretations at a larger scale are needed.

Recommendation 2. **We recommend that the governments of both Canada and BC take steps to gain significantly higher levels of understanding of the sea-bottom and sub-surface conditions of the BC offshore in general, with an early and specific focus on the Queen Charlotte Basin and Hecate Strait areas.**

5.3.2 Marine Ecosystems

While we note below a number of the key physical parameters that must be considered in relation to most offshore activities, including oil and gas, and which like sea-bottom conditions influence habitat variability, it is essential to keep in mind that there is need for a more comprehensive data-base and information system for all aspects of the marine ecosystem.

There are large gaps in our understanding of the impacts on marine biota of acoustic phenomena such as seismic surveys, production rig and drilling noises, or passing ships, but studies of this kind are difficult to conduct on a comprehensive scale, and there is little interest in doing them as long as a moratorium on these activities is maintained. In the meantime, major changes in technology have been introduced, such as air guns in place of explosives for seismic surveys, and in some offshore regions, including those of eastern Canada, the use of air guns and other acoustic devices is subject to strict regulatory controls.

A rich and diverse ecosystem such as the Queen Charlotte Basin presents a number of options for sustainable economic benefit, including fisheries and tourism. But under any of these options, as well as under oil and gas production, serious disturbance to habitat or any biological features could ensue and possibly cause damage to the overall ecosystem; and there is the possibility that this damage might be irreversible. If this should happen as the result of any one activity, then the potential benefits available from the other options would be reduced.

There is concern among biologists and other scientists that the marine biota of BC is threatened by a proliferation of uses. The Panel emphasizes the need to address the deficiencies of knowledge in these areas of scientific knowledge. Reference to research in other offshore areas provides valuable guidance to researchers in BC, but this kind of knowledge is not a substitute for the regional and site-specific research needed in the event of offshore exploration and development.

Recommendation 3. **We recommend that, before any new industry is introduced into a specific marine ecosystem such as the Queen Charlotte Basin, action be taken to establish a comprehensive set of pre-perturbation baseline data on the biota, including life-cycle histories of different species and their habitats, so that we can understand and assess which aspects of the marine ecosystem might be most at risk from the proposed development, and evaluate the population- and community-level consequences that may result.**

5.3.3 Oil-Spill Response and Countermeasures

In the early years of oil and gas operations, especially on land in the period before the 1950's, legally sanctioned controls were often weak, at least in practice. Now the oil and gas industry is highly regulated world-wide, and in a technically advanced country such as Canada the regulatory regime is extremely strict, not least as it affects offshore operations. Indeed today it may be among the strictest in the world. Moreover, it appears that the Canadian oil and gas industry, compared with any other extractive industry, has a good record in compliance. The fact is that less than 2% of the oil spilled into the sea comes from offshore oil rigs and production platforms, while a combined total of 45% comes from maritime transportation, (shipping 33% and tankers 12%).

As Appendix 18 indicates, spills larger than 50 barrels have decreased dramatically over the last two decades, due to both improved technology and higher standards in offshore operations. Likewise, the risk of a blowout has been reduced to very low probability: the only recorded one in Atlantic Canada occurred in 1984 and involved only 1500 barrels of condensate. The same is not true for the shipping and tanker industries, which provide cause for concern about oil-spill response and countermeasures.

Atlases for oil-spill response and countermeasures have been developed for the west coast of Vancouver Island, the southern Strait of Georgia, and Burrard Inlet (underway), which provide information on coastal biophysical and human use, resources, and the sensitivity and vulnerability to both oiling and clean-up of these regions. We note that such reports as these have not yet been prepared for other areas such as the QCB.

Recommendation 4. **We recommend that the governments of both Canada and BC set a high priority on completion of critical data-bases, as well as the enhancement of capabilities for oil-spill responses and countermeasures, both for the coast in general, and particularly for areas likely to be designated for offshore exploration.**

5.3.4 Capacity Building

Oil and gas exploration would bring with it the need for the development of expertise and capacity to manage and sustain it in the best interests of all stakeholders. We identify four approaches that we consider to be essential.

The building or re-building or strengthening of **scientific and regulatory capacity** in the agencies of the provincial government and the BC-based agencies of the federal government is crucial. Since 1986 when the moratorium was last reviewed, there has been stagnation or decline, albeit interspersed with sporadic enhancement, of scientific expertise among the related ministries and laboratories of both the British Columbian and Canadian governments. Recent examples include the loss of six of the twelve seismic monitoring stations in the Queen Charlotte Islands, and there have been large, indeed excessive, cuts in funding of federal agencies in BC that have seriously crippled functions like fishery stock and habitat assessment, monitoring and enforcement. Over this period the Coast Guard was integrated with DFO and much of the DFO fleet eliminated, resulting in higher ship costs and lower levels of service to both science and enforcement. Comparable cuts have been made to provincial agencies, perhaps the most disturbing being the proposed dramatic down-sizing of the BC Geological Survey. The evidence suggests that at present there is insufficient capacity for the research, assessment, monitoring and management needed to provide an adequate baseline knowledge framework for ocean and coastal policy-making.

Recommendation 5. **We recommend strengthening and re-building of federal and provincial expertise in BC to ensure adequate scientific and regulatory/administrative capacity in agencies that would be given responsibilities in the event of a decision to initiate the process of offshore hydrocarbon development.**

(iii) any specific government actions that should be taken prior to a decision on whether to remove the current provincial moratorium

5.4 Procedural Considerations

In the present context, the decision whether or not to end the present blanket moratorium policy is fundamentally one of procedure. While the Panel sees no scientific or technical rationale for its retention, it does recognize the importance of addressing knowledge gaps and other problems, should the moratorium be ended.

In order to consider the science and technology dimensions of any decision on whether to end the moratorium, the Panel has had to ask what the moratorium actually is, how it could be removed, and what would be the situation subsequently. According to the dictionary, a moratorium is a temporary prohibition or suspension of an activity. The original legal authority for a prohibition of offshore exploration in BC is cloudy, but includes a federal announcement in 1972, a provincial Order-in-Council in 1982, and further provincial announcements in 1989. However, the Note associated with the 1982 Order in Council that carried the prohibition on drilling in the Inland Marine Zone was removed by a BC Regulation in 1994. Moreover, it is the Panel's understanding that the current federal moratorium does not rest upon any legislative foundation. So it seems there is no moratorium formally in place, either federally or provincially.

The Panel is, therefore, inclined to take the view that concerns with the "current moratorium" are conceptual and procedural in nature, and that no legislative action is necessary to revise the existing moratorium "policy" before inviting concrete proposals to initiate exploratory drilling and related activities by interested proponents. Any such proposals would then be subject to the existing legislative and regulatory apparatus, including specifically the Canadian Environmental Assessment Act, the British Columbia Environmental Assessment Act, and the Canadian Council of Ministers of Environment Policy on Canada-Wide Environmental Harmonization, under which a bilateral Canada-British Columbia Environmental Accord provides for an integrated joint environmental assessment and review process.

However, there are several important things that would need to be done before there could be any expectation of investor interest, public or private, in initiatives in the BC offshore. The Panel notes that the key preconditions have been spelled out already by industry, First Nations, civil society organizations and community leaders. These include:

> Development of an integrated federal-provincial regulatory framework. (The Canadian Environmental Assessment Act and the British Columbia Environmental Assessment Act are undergoing review and amendment, and the existing Canada-British Columbia bilateral accord on harmonized assessment expires April 2002 and must be renegotiated.);
>
> Negotiation of a Pacific Accord that provides for agreed federal-provincial and First Nations revenue-sharing and fiscal and management arrangements;
>
> Clear delineation of sensitive or vulnerable areas and definition of marine reserves, protected areas and conservation areas essential to preserve biodiversity and ensure ecosystem integrity, so that industry and others will be able to develop proposals for offshore activity with a clear initial understanding of any areas that must be off-limits; and
>
> Development of capacity to build baseline data and assess the state of the ecosystem, including natural and human components, and the impact of continuing activities, and capacity also to undertake quantitative risk analysis, valuation and assessment spanning the full range of strategic options.

Thus, in the present situation, the decision on whether or not to remove the present blanket moratorium seems to be fundamentally one of procedure, not science and technology. While the Panel sees no scientific or technical rationale for retention of the moratorium, it does recognize the importance of knowledge gaps and of steps that must be taken should the moratorium be ended. The balance of this text is oriented to this purpose.

(iv) any specific conditions or parameters that should be established as part of a government decision to remove the moratorium.

5.5 Regulatory Regime

5.5.1 Design of the Regulatory Structure

In Chapter Three of this report, the Panel identifies potential threats to the marine ecosystems of British Columbia, including the potential effects of oil pollution. But, as noted before, very little of the oil in the sea comes from offshore production. Most of the threats to marine ecosystems arise from other uses of offshore waters, and more specifically from a wide range of land-based (coastal and upriver) activities. For example, many in the BC biological research community, noting the accumulation of wastes discharged into BC waters from a growing volume of vessel traffic, now augmented by a growing cruise ship industry, point to the need for stricter controls over vessel-source pollution in general, and routine discharges in particular. The Panel favours a strengthening of efforts to protect marine ecosystems through more effective controls, but it does not find convincing evidence that the introduction of offshore installations and the commencement of drilling operations off the coast of BC should continue to be banned for general ecological reasons. Obviously, however, comprehensive data are required with respect to critical components of the ecosystem in advance of any exploration activity, along with a commitment to monitor and assess changes over the long term and take appropriate action in the light of any changes.

Marine ecosystems reflect a high degree of physical, chemical and biological variability. Accordingly, federal and provincial governments today have responsibilities for environmental policy related to coastal waters, including the establishment of conservation or protected areas. We note a particular need to focus on sensitive areas (e.g. sponge reefs, spawning and nursery grounds) or vulnerable species (e.g. killer whales, abalone).

Because of the recent history of offshore oil and gas exploration and development in eastern Canada, there is a sophisticated regulatory and management regime shared jointly by the federal and provincial governments. These systems are in place and are not significantly dependent on the need for new scientific or technical research.

Recommendation 6. **Should the moratorium be removed, the government should ensure, thorough appropriate consultation, that it has an up-to-date and properly resourced regulatory and management regime in place.**

5.5.2 Risk and the Role of the Regulatory Regime

At international and national levels, several sectors of natural resource development and management have been marked in recent years by divisions among specialists on the weight that should be given to precautionary considerations in situations where there is a credible risk of substantial environmental damage arising from any project under consideration. Environmental lawyers, in particular, have argued over the question of whether the need for reasonable precaution should be treated as a universally binding legal rule, a generally applicable legal principle, a standard applicable in special situations, or merely a guideline to prudent use.

From a scientific point of view offshore hydrocarbon exploration and development cannot be undertaken without some impacts on the environment, and the objective should be to maintain risks at an acceptable level and to mitigate them immediately and effectively. Safety has been improving in the industry, and improved techniques and methodology are available for assessing and dealing with risks and providing a basis for decisions related to offshore exploration and development. This will be helpful not only in supporting technical decisions, such as procedures for mitigation of oil spills, effluent discharges and type of drilling fluid to be used, but also in designing regulatory measures.

Recommendation 7. **We recommend that, before actual exploration and related activities take place, a quantitative risk analysis be undertaken as a vehicle for decision-making by the various stakeholders. A thorough cost-benefit analysis should also be undertaken to assess alternative strategies for uses of the marine ecosystem.**

5.5.3 Seismic Surveys

Recently the Joint Nature Conservation Committee (JNCC) in the UK has established specific seismic survey guidelines with regard to marine mammals, and member companies of the UK Offshore Operators Association and the International Association of Geophysical Contractors have indicated they will comply with these guidelines. We note that such acoustic disturbances could have effects beyond marine mammals and on other components of the marine ecosystem.

Recommendation 8. **This Panel urges application of guidelines for reducing the impacts of seismic exploration on the ecosystem, as license conditions for any oil and gas exploration off the BC coast.**

5.5.4 Rig and Pipeline Regulation

The Queen Charlotte Basin is subject to occasional severe storms, and the Northeast Pacific experiences fairly frequent earth movements under the ocean, which can trigger tsunamis. However, platforms can be designed to withstand the forces caused by these events and Canadian regulations require the highest possible standards of engineering design and construction ever applied to this sector of technology.

As noted above, pipeline delivery systems would be preferable to shuttle tankers, given that tankers and other vessels contribute far more to oil pollution of the oceans than oil and gas production platforms. However, should pipelines be used to export oil from production platforms, it would become more critical to have careful site-specific surveys and understanding of the local earthquake regime, as well as mechanisms to ensure that pipelines are designed, emplaced and monitored for the maintenance of maximum integrity.

Recommendation 9. **We recommend that regulations require, were production to take place in the BC offshore, that export lines from the production platforms be tied into pipelines, as opposed to offloading the oil into shuttle tankers by way of buoys. We further recommend that pipeline monitoring and shut-down systems be employed that would maintain maximum pipeline integrity and the least possible environmental risk. Site-specific surveys and assessments should be required to establish the most appropriate pipeline route.**

5.5.5 Conflicting Regulatory Priorities

We note that a bill has been introduced recently in the Nova Scotia Legislature (Bill 97, November 2001) to address perceived problems of conflicting priorities in the regulation of offshore health and safety matters. This and other issues of institutional design will demand close attention in any new offshore regulatory framework to be established in British Columbia, and the lessons to be drawn from experience elsewhere to date should be carefully assessed.

Recommendation 10. **We recommend that the separation of the regulatory authority for health and safety matters from the organi-**

zation that issues the exploration and production licenses is something which should be addressed in any new BC regulatory regime.

5.6 Supportive Strategies

5.6.1 Human Resource Development Strategy

One of the lessons learned from the eastern Canada offshore experience is that new opportunities for provincial and local employment can be lost in the absence of a concerted, multi-agency planning effort. The job market does not adjust quickly or automatically when a decision is made to begin or resume exploratory offshore drilling. It is essential to alleviate the already difficult challenges in recruitment of skilled and highly qualified people.

An appropriate technical training program would be designed to encompass a wide variety of technical skills covering the entire range of the ocean technology industry. BC educational institutions that specialize in vocational training should be helped to develop offshore-related courses in consultation with the appropriate sectors of the petroleum industry and others in BC, and perhaps with specialized institutions elsewhere. Such courses should be made available throughout BC

Recommendation 11. **If the BC government should decide to begin preparations for offshore exploration, one of its first steps should be to design a strategy for the training of British Columbians for the wide range of job requirements and opportunities associated with these activities.**

5.6.2 Coastal Community Development Strategy

As soon as possible following any decision to proceed with offshore development, the first steps should be taken to prepare the affected coastal communities for their potential relationship with the industry. A strategy should be developed before the industry has begun to move in. One of the industry's obligations should be to clarify the nature of the economic opportunities that may be created, and the pattern of social impacts and benefits that might be experienced. Such a strategy should also be designed so that the incoming industry has an opportunity to learn about the social history of the coastal communities, the richness of their traditions, and the nature of their expectations.

Recommendation 12. **The Panel recommends that, at the earliest stage of any offshore oil and gas activity, a strategy be developed to ensure effective participation of First Nations and Northern BC coastal communities in this new industry.**

5.6.3 Ocean Technology Industry Development Strategy

The private sector invariably leads in the creation and deployment of new activities, new business development, and ultimately the creation of new wealth. Yet entrepreneurial success often depends on a supportive government strategy. In British Columbia an ocean technology sector already forms an important part of the province's high-tech business community, which consists largely of small and medium sized enterprises (SMEs) that produce equipment and electronics for both domestic and export markets. These SME products include ships outfitting, engines, pipes, electronic navigational charts, navigation systems, remote and autonomous underwater vehicles, marine communications technology, advanced marine acoustics, underwater sensors, and advanced radar technology, among others.

An offshore oil and gas industry off the coast of BC would open up new opportunities for local SMEs in other sectors such as sub-sea equipment related to resource exploration, and the construction and maintenance of production platforms, and would increase the demand for highly specialized services such as ocean charting, sea-floor mapping, the acquisition and interpretation of seismic data, and environmental monitoring and assessment of marine ecosystems affected by offshore activities, to mention only a few. If an oil and gas industry were to develop off the coast of BC, it would likely create a snowball effect within the BC business community and enable it to become a more effective and significant exporter of specialized ocean-related skills and technology, as is happening in eastern Canada.

Such an initiative will rest largely with the private sector, including the academic community, but it is unlikely to happen as long as the moratorium is in place, and if it occurs at all, it will do so more efficiently through closer collaboration with the public sector in the form of joint planning and a clear provincial strategy.

Recommendation 13. **We recommend that, should the moratorium be removed, the BC government consider what steps it can take in partnership with the private sector to build upon any oil and gas development as the main driver of renewed marine engineering and construction sectors, as well as a broader-based ocean technology industry.**

5.6.4 Consultation Strategy

In an open, democratic society such as ours it is normal for governments to accept responsibility for cultivating appropriate consultative relationships with stakeholders and others with special knowledge, especially in situations that are complex and controversial to some degree. There are at least four constituencies.

The General Public: The present and previous governments of BC have maintained, at least intermittently, a kind of dialogue with the electorate on moratorium issues, which today is reflected in the work of the Northern Caucus of the governing party. In recent years the process of consultation was institutionalized by the establishment of the BC Northern Development Commission, which undertook extensive consultations in the North. The Panel presumes that a policy of public consultation, through the Northern Caucus or some other means, would be maintained if a decision were made to lift the provincial moratorium.

Northern Coastal Communities and First Nations: Experience elsewhere proves that the smoothest transition to an offshore development economy tends to occur when the local community and other directly affected parts of the population have been consulted throughout the entire process of development In British Columbia there is a special need for the players, from the beginning, to work with the First Nations coastal communities of Northern BC and their representatives on basic issues of entitlement, revenue-sharing, capacity-building, and governance within a framework of constructive collaboration.

The Research Community: The history of offshore development around the world shows that national governments do not always display much interest in benefiting from the past experience of other countries in technically complex sectors like offshore development, despite the availability of information in various forms such as model statutes and training manuals. However, at an early stage of its offshore planning, Newfoundland chose to consult with the public and private sector institutions carrying out oil and gas operations in the North Sea. Valuable lessons were learned, especially through intense consultation and interaction with the responsible British, Scottish and local agencies in Northern Scotland, Norway, and other countries around the North Sea. Nova Scotia followed suit, albeit within a shorter time-frame.

Other Jurisdictions: The Panel believes it will be useful for the BC government to establish a continuing consultative process with the governments of Newfoundland and Nova Scotia, in order to avoid unnecessary mistakes in the implementation of any decision to begin preparations for oil and gas development off the coast of BC Inter-regional technical consultations outside Canada would also be useful, especially, it seems, in Alaska and California, and perhaps also in Scotland and Norway. Moreover, these consultations should extend to the research and business communities in these jurisdictions.

Recommendation 14. **The Panel recommends that the BC government enter into consultations, at an early stage of any post-moratorium planning, with at least the above four constituencies: the general public, the northern coastal communities and First Nations, the research community, and other jurisdictions.**

5.6.5 Information Strategy

Public Access to Information: If the BC government decides to lift the moratorium, it will be important, in the Panel's view, to have a public information strategy as a corollary to its consultation policy. Ideally, a designated agency of the provincial government should be made responsible for maintaining a Web Site with information on current or recent developments related to exploration and subsequent phases of offshore oil and gas operations. Selected information, including certain scientific and technical data, should also be made available in non-electronic form.

Science and Local Knowledge: By definition, scientific and technological knowledge about the offshore is usually highly technical in nature. Both the acquisition and interpretation of such information is very largely the domain of the research community, and most of it tends to be confined to scientific and technical journals and reports. Despite the dominant role of the research community in this technical sector, the Panel believes that in certain contexts there is much to be learned from the observations and experience of seafarers in coastal and offshore areas, and of coastal communities. Most local knowledge tends to be anecdotal in form, or derived from logs and personal records, and some exists entirely as oral knowledge. Yet the Panel believes that valuable insights might become available to policy-makers from current BC research on local knowledge inputs.

Recommendation 15. **The Panel recommends that, if the provincial moratorium is ended and relevant technical research begins on an expanded scale, the BC government might wish to consider setting up an arms-length mechanism (e.g. through the province's educational institutions) that would both provide the general public with periodic summaries or abstracts of the technical literature, written in non-technical language, and also receive, interpret and communicate data from local and independent observers.**

5.7 Conclusion

There are a number of regional and site-specific gaps or inadequacies of data, knowledge, understanding, and indeed infrastructure and capacity, which must be addressed in the early stages following any removal of the moratorium. Nevertheless, oil and gas are being produced offshore under the full range of conditions found in virtually every variety of natural environment in the world, and clearly there have been steady improvements in the science, the technology and the regulations enabling and governing such activities. We conclude overall that, while there are certainly gaps in knowledge and needs for intensification of research and a continuing commitment to baseline and long-term monitoring, these do not preclude a decision on the moratorium. There is no inherent or fundamental inadequacy of the science or technology, properly applied in an appropriate regulatory framework, to justify retention of the BC moratorium.

BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT

REPORT OF THE SCIENTIFIC REVIEW PANEL

January 15, 2001

VOLUME TWO:
APPENDICES

BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT:
VOLUME II – APPENDICES TO THE REPORT OF THE SCIENTIFIC REVIEW PANEL

(Volume I: BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT:
REPORT OF THE SCIENTIFIC REVIEW PANEL)

Submitted to the BC Minister of Energy and Mines, Hon. Richard Neufeld

January 15, 2002

Panel Members:

David Strong (Chair)	David Strong is Professor in the School of Earth and Ocean Sciences at the University of Victoria. He was President and Vice-Chancellor at the University of Victoria from 1990 to 2000. He serves on the governing council and the executive committee of the National Research Council of Canada and the Research Council of the Canadian Institute of Advanced Research. Strong is the past Vice-President of Memorial University in St. John's, Newfoundland, where he was also special adviser to the President. He was a Member of the Standing Advisory Committee on University Research of the Association of Universities and Colleges of Canada, and served on British Columbia's Advisory Council on Science and Technology and the Newfoundland and Labrador Advisory Council on Science and Technology, among others.
Patricia Gallagher	Patricia Gallaugher is Director of Continuing Studies in Science and Director of the Centre for Coastal Studies at Simon Fraser University. She was a Professor of biology at Memorial University and is co-editor of a volume on marine conservation, *Waters in Peril*. Gallaugher participated in the North American Commission for Environmental Cooperation workshop on aquatic invasive species in the spring of 2001. Gallaugher has a PhD in bioscience from Simon Fraser University.
Derek Muggeridge	Derek Muggeridge is Dean of the Faculty of Science at Okanagan University College, where he is also Associate Vice-President of Research. He is President of Offshore Design Associates Ltd., which provides specialist services in offshore safety and wave and ice structure interaction. Muggeridge is a Member of the Awards Committee of the Science Council of British Columbia and a Member of the Canadian National Committee / Engineering Committee on Oceanic Resources. He was the Director of the Ocean Engineering Research Centre at Memorial University. Muggeridge has a Bachelor of Science from California State Polytechnic University, and a Master's of Science and a PhD in aerospace engineering, both from the University of Toronto.

BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT

REPORT OF THE SCIENTIFIC REVIEW PANEL

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Appendix 1: Offshore Oil and Gas Scientific Panel – Terms of Reference

I. Introduction

October 19, 2001

The July 24, 2001 Speech from the Throne stated that Government would "explore the enormous opportunities of offshore oil and gas", and would appoint a scientific panel to "ascertain whether those resources can, in fact, be extracted in a way that is scientifically sound and environmentally responsible, with its initial findings being tabled by January 31, 2002".

This paper sets out the terms of reference for the Scientific Panel, and describes how Government will meet this commitment.

II. Context

Although the "offshore" includes all areas to the seaward, including the West Coast of Vancouver Island, "offshore oil and gas" refers primarily to the Queen Charlotte Basin, encompassing Hecate Strait, Queen Charlotte Sound and Queen Charlotte Strait. This basin is believed to have significant hydrocarbon resource potential. Although no commercial wells have been discovered, the Geological Survey of Canada currently estimates 9.8 bbo and 25.9 tcf of natural gas may be found in the basin.

British Columbia has restricted offshore oil and gas activity since 1959, with the exception of a brief period from 1965 to 1966. The Province has issued three separate orders in council (1959, 1966 and 1981), reserving the seabed floor off the Queen Charlotte Islands and Vancouver Island to the Provincial Crown.

A federal moratorium has also been in place since 1972. Negotiations between the Province and Canada on a "Pacific Accord" reached agreement on many topics by the late 1980's. However, significant issues related to First Nations, decision-making authority, financial matters, and the conditional status of the Accord remained outstanding when negotiations ended in 1988.

Concurrent with the Pacific Accord negotiations, Canada and the Province conducted a joint environmental assessment of offshore activities. In 1986, the assessment report, "Offshore Hydrocarbon Exploration", provided 92 recommendations on actions Government should take to ensure offshore oil and gas activity occurred in an environmentally sound manner. However, in 1989, as a result of public concerns over oil spills, the Province announced offshore drilling would be prohibited for at least five years; this was subsequently extended indefinitely.

III. Related Government Initiatives

The Ministry of Energy and Mines has contracted Jacques Whitford Environment Ltd. (JWEL), an international consulting firm, to undertake an independent study of offshore oil and gas technology based on the 1986 Report and a 1998 report prepared for, but never released by, the government of the day. JWEL will comment on scientific and socio-economic matters and, where appropriate, will identify "lessons learned" from other jurisdictions as well as "information gaps". The final report from JWEL is expected on October 19, 2001.

As a complementary initiative, Government has established a Northern Caucus to "consult with northern residents and community leaders" regarding a range of issues relevant to the North, including offshore oil and gas development.

IV. Mandate

The Scientific Panel will provide advice to the Minister of Energy and Mines on whether offshore oil and gas activity can be undertaken in a scientifically sound and environmentally responsible manner. In particular, the Panel will advise on:

The scientific and technological considerations relevant to offshore oil and gas exploration, development and production;

Further research or studies that should be undertaken to advance the "state of knowledge" on these considerations;

Any specific Government actions that should be taken prior to a decision on whether to remove the current moratorium; and,

Any specific conditions or parameters that should be established as part of a Government decision to remove the moratorium.

V. Tasks

The Scientific Panel will be expected to undertake the following tasks:

review and provide analysis of the JWEL report;

summarize public and stakeholder response to JWEL report;

undertake additional literature reviews of relevant publications;

solicit submissions and/or commentary by other relevant scientists or other experts as required; and

prepare a final report for the Minister in accordance with the mandate above.

The Scientific Panel will not hold public meetings or hearings (these are the responsibility of the Northern Caucus). However, the Scientific Panel may invite relevant experts to provide information or opinions.

VI. Accountability

The Scientific Panel will be appointed by, and will provide advice to, the Minister of Energy and Mines. The Scientific Panel will operate independently from Government, but any decisions based upon its advice, particularly in relation to the current moratorium, will be made by Cabinet.

VII. Structure and Composition

The Scientific Panel will consist of three (3) internationally known and experienced academics, each with broad, relevant experience and expertise.

The Scientific Panel will have the capacity to include additional experts as "ex-offico" or "subject specific" members, as required to ensure that all relevant disciplines and perspectives are considered. These additional members would be appointed by the Minister of Energy and Mines on the recommendation of the Scientific Panel.

The Scientific Panel will receive project support from the Maritime Award Society of Canada (MASC). This support will include development of a project overview and workplan, coordinating meetings, managing submissions, and drafting work on the Scientific Panel's report to the Minister.

A senior official from the Ministry of Energy and Mines will be the liaison between the Ministry and the Scientific Panel.

Members of the Scientific Panel are identified in Appendix A. The MASC is described in Appendix B.

VIII. Timeframe

The Scientific Panel will deliver its final report to the Minister of Energy and Mines no later than January 15, 2002. The Panel will work through the following phases:

Phase 1: Preparation (conclude October 26, 2001)

Post JWEL report on the Ministry website (University of Northern British Columbia will link into Ministry website)

Finalize organizational arrangements for Scientific Panel and MASC

Phase 2: Investigation and Review (conclude December 15, 2001)

Feedback on JWEL report collected from public, interest groups, etc.

Panel to review and comment on JWEL Report

Panel to investigate supplementary literature

Panel to formulate recommendations

Panel to seek additional submissions as required

Phase 3: Documentation and Submission (conclude January 15, 2002)

Documentation of Report
Documentation of non-technical executive summary
Collation of Public Commentary
Submission of Report to Government

APPENDIX A

Panel Members

David Strong (Chair)	David Strong is Professor in the School of Earth and Ocean Sciences at the University of Victoria. He was President and Vice-Chancellor at the University of Victoria from 1990 to 2000. He serves on the governing council and the executive committee of the National Research Council of Canada and the Research Council of the Canadian Institute of Advanced Research. Strong is the past Vice-President of Memorial University in St. John's, Newfoundland, where he was also special adviser to the President. He was a Member of the Standing Advisory Committee on University Research of the Association of Universities and Colleges of Canada, and served on British Columbia's Advisory Council on Science and Technology and the Newfoundland and Labrador Advisory Council on Science and Technology, among others.
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APPENDIX B

Maritime Award Society of Canada http://web.uvic.ca/masc/

The Maritime Awards Society of Canada is a registered charitable organization established to fund scholarships for Canadian university graduate students in marine and coastal affairs. At present MASC donations support scholarships at four universities: Victoria, Memorial, Dalhousie and Calgary. In addition, MASC has undertaken to provide a public service through annual workshops, public conferences, and other educational activities that are designed to raise awareness and enhance understanding of public policy issues related to the ocean in general and to Canada's coastal waters.

Appendix 2: Some Useful Websites

Government

Alaska Oil and Gas Association: Current Issues, 1998. www.aoga.org/index

American Petroleum Institute http://www.api.org/ehs/gulf/LGL%20Report.htm

Atlantic Canada Petroleum Institute http://agc.bio.ns.ca

Atlantic Canada Petroleum Institute http://www.acpi.ca/main.html

BC Decision Support Services (DSS) of the Ministry of Sustainable Resource Management www.gov.bc.ca/dss.

Bedford Institute of Oceanography http://www.mar.dfo-mpo.gc.ca/e/s_bio.html

Canada-Nfld. Offshore Petroleum Board http://www.cnopb.nfnet.com/

Canada-Nova Scotia Offshore Petroleum Board http://www.cnsopb.ns.ca/

Canadian Association of Petroleum Producers – CAP http://www.capp.ca/

Canadian Coast Guard http://www.ccg-gcc.gc.ca

Canadian Environmental Assessment Agency http://www.ceaa.gc.ca/

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): http://www.cosewic.ca

Department of Fisheries and Oceans http://www.dfo-mpo.gc.ca/index.htm, http://www.dfo-mpo.gc.ca/frcc/

Environment Canada http://www.ec.gc.ca/envhome.html

Environmental Studies Research Funds http://www.esrfunds.org/home%20page%20eng.htm

Global Ocean Observing System (GOOS). http://ioc.unesco.org/goos/

Marine Environmental Data Service (Fisheries and Oceans Canada) http://www.meds-sdmm.dfo.gc.ca

National Energy Board http://www.neb.gc.ca/

National Research Council – Canada Institute for Scientific and Technical Information http://www.nrc.ca/cisti/cisti_e.shtml

National Research Council Innovation Centre, Vancouver (fuel cell research) http://www.nrc.ca/icvan/

Natural Resources Canada Geological Survey of Canada (Atlantic) http://www.nrcan-rncan.gc.ca/homepage/index.html

Natural Resources Defense Council. http://www.nrdc.org

Nova Scotia Department of Environment http://www.gov.ns.ca/enla/

Nova Scotia Petroleum Directorate http://www.gov.ns.ca/petro/home.htm

Oceans Act. http://www.pac.dfo-mpo.gc.ca/oceans

Oceans and Coasts at Rio +10: http://www.udel.edu/CMS/csmp/rio+10

Offshore/Onshore Technologies Association of Nova Scotia –OTANS http://www.otans.ns.ca/index.html

Precautionary Principle http://www.dfo-mpo.gc.ca/cppa

Public Review on the Effects of Potential Oil and Gas Exploration and Drilling Activities within Exploration. Cape Breton, Nova Scotia. http://www.publicreview.ns.ca/prceng/

SeaMap: http://seamap.bio.ns.ca

United Kingdom Offshore Operators Association http://www.oilandgas.org.uk/

Other Organizations/Associations

American Association of Petroleum Geologists http://www.aapg.org/

Canadian Association of Petroleum Producers http://www.capp.ca/

Canadian Centre for Marine Communications http://www.ccmc.nf.ca/

Canadian Geospatial Data Infrastructure www.geomatics.org/Report/techreport2/html)

C-CORE http://www.c-core.ca/index.html

Cook Inlet Keeper http://www.inletkeeper.org/

EdgeNet http://www.edge-online.org/

Environmental Impact of Offshore Oil and Gas Exploration and Production http://www.offshore-environment.com

Fisheries Resource Conservation Council Joint Nature Conservation Committee – United Kingdom http://www.jncc.gov.uk/

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) http://gesamp.imo.org/no62/index.htm.

Maritime Awards Society of Canada http://web.uvic.ca/masc

NEPTUNE http://www.neptune.washington.edu http://www.neptunecanada.com/

Newfoundland Ocean Industries Association http://www.noianet.com/

Nova Scotia Petroleum Directorate http://www.gov.ns.ca/petro/

Ocean Mapping Group, Univ. of New Brunswick http://www.omg.unb.ca/

Offshore/Onshore Technologies Association of Nova Scotia http://www.otans.ns.ca/

Oil Spill Intelligence Report http://www.cutter.com/osir/index.html

Petroleum Communication Foundation http://www.pcf.ab.ca

Scottish Fishermen's Federation http://www.sff.co.uk

Sierra Club of Canada http://atlantic.sierraclub.ca/, eastern Atlantic http://www.sierraclub.ca/eastern/

VENUS

Industry

Alaska Oil and Gas Association (http://www.aoga.org)

American Petroleum Institute http://www.api.org/ehs/gulf/LGL%20Report.htm

Atlantic Canada Petroleum Institute http://www.acpi.ca/main.html

Blue Energy Canada Inc. www.bluenergy.com.

Canadian Association of Petroleum Producers http://www.capp.ca/

Corridor Resources http://www.corridor.ns.ca/

Mobil Oil Canada http://www.exxon.mobil.com/

Hunt Oil http://www.huntoil.com/

Imperial Oil Resources http://www.imperialoil.ca/

Marathon Oil Company http://www.marathon.com/

Newfoundland Ocean Industries Association http://www.noianet.com

Offshore/Onshore Technologies Association of Nova Scotia –OTANS
http://www.otans.ns.ca/index.html

PanCanadian Energy Corporation http://www.pancanadian.ca/

Petro-Canada http://www.petro-canada.ca/petro.html

Shell Canada Limited http://www.shell.ca/

United Kingdom Offshore Operators Association http://www.oilandgas.org.uk/

Whiterose http://www.huskywhiterose.com/html/project_description/project/project2.html

Appendix 3: Lifting the moratoria[1]

The existing jurisdictional and regulatory setting.
The "existing state of affairs" is complex. It is necessary to distinguish among issues of constitutional jurisdiction, ownership, resource revenue sharing and regulatory responsibilities.

Geographically, issues of jurisdiction have been partly resolved but some uncertainty remains. At least as early as 1957, probably much earlier, British Columbia put forward claims to the offshore area, asserting Crown reserves over areas of the continental shelf out to the (then) boundaries of Canada's territorial sea. Initial industry activity in exploration and drilling took place in the 1960s in a muddled setting, with confusion not just between federal and provincial permitting and licensing, but also with federal departments of energy (Energy, Mines and Resources) and environment (initially Fisheries and Forestry) announcing conflicting positions with respect to drilling permits.

By now the jurisdictional questions have been settled to some extent. "Respecting federal-provincial constitutional jurisdiction over offshore areas, Supreme Court of Canada cases have determined [1967] that the federal government has, vis-à-vis British Columbia, exclusive legislative authority regarding all waters and seabed areas west of Vancouver Island and the Queen Charlotte Islands. The waters and ocean floor between Vancouver Island and the mainland have been held [1984] to be within provincial jurisdiction. There is legal uncertainty regarding federal-provincial jurisdiction over the waters and sea floor between Vancouver Island and the Queen Charlotte Islands (Queen Charlotte Sound) and the waters and sea floor landward of the Queen Charlotte Islands (Hecate Strait)." (Cumming and McDorman, p.7)

In a footnote to the above comment, it is noted that in 1981 British Columbia declared that the waters and seabed landward of the straight baselines and fishery lines established along the west coast (the area of Hecate Strait and Queen Charlotte Sound) were a provincial Inland Marine Zone. (BC Order in Council 1347, 4 June 1981, made pursuant to section 87(g) of the Petroleum and Natural Gas Act, Rev. Stat. of BC 1979, ch 323). It is also speculated that "a clear articulation by the federal government of Canada that the waters of the Queen Charlotte Sound and Hecate Strait were internal waters would provide considerable strength to the BC position that the seabed of these waters, and the possible hydrocarbon resources located therein, are under provincial jurisdiction" (loc.cit.).

Thus it appears that the federal government would have authority to issue licenses or rights in the territorial sea, west of the low water mark of the outer coastline, that is, roughly, west of a line running north along the western side of Vancouver Island and the Queen Charlotte Islands, while in the internal waters landward of such a line, though the ownership by the province may be acknowledged, activities would be subject to joint jurisdiction. In similar situations of confused or overlapping jurisdiction, companies have dealt with the problem by holding both federal and provincial licenses, and governments have coordinated their issue of licenses correspondingly. (It should be emphasized, however, that such licenses now do not confer any right to specific exploratory or production activities; they merely secure the exclusive right of the licensee to apply for authorization to undertake such specific activities in the designated area or parcel of land.)

"The aboriginal rights component of the Canadian Constitution has implications for stakeholders that are potentially as significant as those arising from considerations of federalism. This is because offshore oil and gas projects may well be challenged in court on the basis that they infringe the aboriginal rights of First Nations in the area....In the context of offshore drilling, it is fishing rights that are most likely to be at issue. Aboriginal title could also be implicated, although this is considerably less likely...An offshore oil and gas project might interfere with an aboriginal fishing right if it is located in waters where an aboriginal fishing right is exercised and in a manner that potentially threatens the fish habitat...Both the federal and provincial governments are bound by s. 35 [of the Constitution Act]. Accordingly an infringement would occur where either government approves an offshore oil and gas project that (a) jeopardizes the fish supply which an aboriginal group has the constitutional right to fish or that (b) is located in waters subject to aboriginal title....[To justify such an infringement] meaningful consultation with aboriginal people, conducted in good faith, would almost certainly be required....In fact, consultation with affected aboriginal peoples is already a legal requirement under environmental legislation....(Extracts from "Offshore Oil and Gas and British Columbia: The Legal Framework. T. Murray Ranking, October 2, 2001.)

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[1] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Rod Dobell and Claire Abbott, University of Victoria – January 2002.

With respect to regulatory responsibilities, however, the federal government has legislative authority respecting "navigation and shipping"; "beacons, buoys and lighthouses" and presumably other structures or platforms; fisheries; and aspects of marine pollution. At the same time, the provincial government has legislative authority over all lands and mineral resources "in the province" and, more generally, through "property and civil rights", all activities that take place in the province. (Cumming and McDorman, p. 9). Such authorities would be exercised simultaneously by both governments in all the geographical regions discussed.

It should be noted that the Oil and Gas Commission was created in British Columbia in 1998 to regulate exploration and production activities onshore in British Columbia, but the legislation is silent on any role with respect to offshore activities. A cursory reading of the mission and purposes shows nothing to exclude application of its powers to offshore resource questions. [See http://www.ogc.gov.bc.ca/whoweare.asp]

Existing provisions for environmental review

It seems reasonably clear that any proposal by a company or consortium of companies to undertake seismic surveys or exploratory drilling would trigger a review under the Canadian Environmental Assessment Act, and probably also under the BC Environmental Assessment Act. (It is not so clear that a bid for a license or exploration rights itself would do so.) Requirements for license or approvals under the Fisheries Act, the Navigable Waters Act, the NEB Act, or the Canada Oil and Gas Operations Act (among possibly many others) would trigger a requirement for an environmental assessment.

It should be noted that a mandated five-year review of the CEAA (1995) led to Bill C-19 being tabled in March, 2001, with proposed amendments to the Act; the Bill received second reading in June, and the Standing Committee on Environment and Sustainable Development began its review of the Bill on December 4, 2001. The Minister's report to Parliament on the review process suggests little dramatic change to existing procedures, but emphasizes the importance of the joint review processes.

In British Columbia the present administration has indicated that as part of its core services review it is reviewing its environmental assessment processes and the present British Columbia Environmental Assessment Act along with many other legislative or regulatory provisions in the arena of land and resource planning, management and use.

The Regulatory Roadmaps Project of Erlandson and Associates provides detailed guides to the existing regulatory approval processes for oil and natural gas exploration and production in various offshore areas. [See http://www.oilandgasguides.org . Unfortunately there exists no such document for BC, but those which have already been created to describe the situation on the Atlantic and Arctic coasts illustrate well enough the extraordinary complexity of the approval and oversight processes involved.

Within the overall framework of a Canada-Wide Accord on Environmental Harmonization negotiated within the Canadian Council of Ministers of Environment, Canada and British Columbia have signed a bilateral harmonization agreement on environmental assessment cooperation. Under this agreement, for any proposal requiring both a federal and a provincial environmental assessment, a harmonized review process would be developed, with the goal of meeting all the requirements for review, federal, provincial or other, through a single unified process. The agreement presently in force provides that where both CEAA and BCEAA are triggered, the joint review process will be undertaken and completed using the BC environmental assessment process.

This present sub-agreement with BC under the CCME Harmonization Framework expires in April, 2002, and must be extended or re-negotiated. In the present setting, with both federal amendments in process and provincial review of its environmental assessment legislation and processes underway, re-negotiation of the harmonization sub-agreement may be difficult or delayed, and hence the provisions for a joint process may be difficult to establish for some time. However, none of this need come into play until there is some industry application to consider. And not all activity necessarily triggers a requirement for review under both Acts; it will be necessary to identify what sorts of applications do so.

As noted below, it seems likely that the process of negotiating some form of Pacific Accord paralleling the existing Atlantic Accords implemented with both Nova Scotia and Newfoundland and Labrador may involve creation of mirror legislation, with either a continuing joint Offshore Board or provision for project-specific independent review panels to carry out necessary environmental reviews and assessments, all entailing increasingly extensive public hearings.

Such a coordinated environmental assessment was carried out for the Sable Island Offshore Energy Project. A five-person review panel was appointed in 1996; the joint review report was released in October 1997. The various regulatory agencies having jurisdiction adopted various recommendations or conditions of the review panel prior to giving their approval to project proposals. (It's worth noting that the precedent of NEB leadership in the Sable Island review process reflected the crucial character of the interprovincial pipeline involved, a matter beyond the powers of the Offshore Board itself. A similar situation does not exist here, so the basis for NEB involvement in a similar review panel might be somewhat different.)

At another level, within the federal government, it appears that any federal move to end the existing policy of refusing to entertain applications for new drilling licenses or for exploratory activity under existing licenses offshore British Columbia would be subject in the first instance to the 1999 Cabinet Directive on Strategic Environmental Assessment of Policy, Plan and Program proposals. This Directive, intended to provide the overarching policy review to complement the legal framework provided by the Canadian Environmental Assessment Act for environmental assessments on projects requiring federal government permits or authorizations, requires that a strategic environmental assessment be undertaken on any general policy or program proposal submitted to a Minister or to Cabinet for approval when implementation of the proposal may result in important environmental effects.

It is not clear whether similar requirements for formal strategic environmental assessment at a policy level exist in BC, but presumably any decision to move forward with a general measure to 'lift the moratorium' will require a Cabinet Submission by the Minister of Energy and Mines; such a Cabinet Submission will require attention to implications with respect to environment and sustainable development. Thereafter provisions of the BCEAA will presumably require that any specific project proposals be reviewed, again presumably under the provisions for a fully harmonized process.

The Moratoria

With this understanding of the current situation with respect to jurisdictional questions, regulatory authorities and assessment processes, we can move on to ask what is the present moratorium, and where matters would rest if it were ended.

The answer seems to be that the present 'moratoria' on exploration for or development of hydrocarbon resources offshore British Columbia currently exist essentially as a legacy of a variety of announcements going back over four decades. As a result of this legacy, both the federal and provincial governments are understood to be unwilling to consider any new claims or applications for licenses to areas of seabed offshore British Columbia, or to entertain proposals for activity under any existing licenses. At the same time, it seems that any existing license holders have been exempted from any obligations to undertake activities as a condition of their license, and thus are in the position of having their existing claims protected, in effect, without the usual obligations to work them.

A fascinating glimpse into the origins—or at least early stages—of the debate is offered by an exchange in Hansard for April 20, 1972. Tommy Douglas, at the time MP for Nanaimo-Cowichan-The Islands, questions whether oil drilling permits issued by the Minister of Energy, Mines and Resources (Donald MacDonald) to Petrotar Development covering 2.7 million acres in Queen Charlotte Sound had or had not been revoked. He noted that David Anderson, at the time MP for Esquimalt-Saanich, had assured the public that no such permits would be issued for exploration of offshore areas without the approval of the Minister of the [then new] Department of the Environment. The Minister of Environment himself [Jack Davis] was quoted as saying there would be action to recover the permits (though it appears this never happened).

In response, Jack Cullen, Parliamentary Secretary to the Minister of Energy, Mines and Resources, enunciated what might be taken as the federal government policy at the time: "With the concurrence of my Minister (the Minister of Energy, Mines and Resources), the Minister of Environment (Mr. Davis) announced in Vancouver on March 13 (1972) that exploration and drilling for oil would be excluded from sensitive offshore zones. Our departments will work together on definition of these offshore zones....If any of Petrotar's permits should fall within environmentally sensitive zones, then we will be discussing with that company the kinds and conditions of work which will not be allowed. I should like to confirm the government's position that subject to this zoning, exploration and drilling will be encouraged in the offshore frontier in strict adherence to regulations currently enforced by my department and judged to be among the most stringent anywhere in the world." (Hansard, pp 1507-1508, April 20, 1972)

Subsequently the federal government position hardened, it seems. Some accounts refer to a mythical 1972 federal Order in Council establishing formally a moratorium on oil and gas drilling, on the recommendation of the Commons Special Committee on Environmental Pollution founded and chaired by David Anderson. In fact the report of this committee dealt with fears of oil spills from tankers traveling the West Coast from Alaska to Washington, carrying oil from the newly-exploited Prudhoe Bay fields. But the expression of these concerns did raise questions about the inconsistency of Canadian battles with the United States over tankers and oil spills while proposals for seismic exploration (perhaps using dynamite) and applications for drilling licenses in Georgia Strait or Queen Charlotte Basin were being routinely approved by another arm of the same Canadian federal government.

An article in the December 31, 2001 issue of *The Globe and Mail* contains the following account of the federal decision at that time. "Mr. Anderson [federal Minister of Environment David Anderson] said he was also personally responsible for the federal moratorium on drilling for oil and gas off the West Coast. He had urged former prime minister Pierre Trudeau to impose the moratorium, arguing that Canada could not logically express concern [in the US] about oil-tanker traffic while allowing oil companies to drill for oil in the same water. The moratorium was imposed in 1972."

Extensive searching, apparently by many people, has not turned up any 1972 Order-in-Council, despite the fact that its existence is asserted in authoritative journals (but with citation only to secondary sources which themselves cite no sources.)

In a personal conversation January 13, 2002, the Minister indicated that he knew of no Order in Council or other formal instrument establishing the moratorium. He noted that many people misunderstand the nature of the moratorium: in fact its central effect is not a prohibition on drilling activity, it is to lift from licenseholders any obligations to undertake work under those licenses, since the government would not be prepared to approve such activities in any case.

In one version, it all seems fairly clear. In the Sierra Legal Defence Fund publication *A Crude Solution* it is said that "the legal mechanism invoking the moratorium is quite simple and could easily be changed..." A box in the text explains the situation as seen by SLDF: "The current provincial moratorium traces back to a 1981 Order in Council, which reserved lands offshore to the province and placed a moratorium on oil drilling. All that is required to lift this moratorium is a new Order in Council. The federal moratorium is even easier to lift. But until such time as it is is, no offshore activity can proceed. 'The [federal] moratorium is just an administrative agreement between the federal and the provincial government' Heather Dabaghi, an adviser on land management for the federal Department of Natural Resources, explained in a Monday Magazine article in May, 1995. 'There's nothing set out in legislation, but periodically we announce that the moratorium is still in place.'

It seems likely that this description refers to a federal government undertaking (following a 1989 BC announcement) not to proceed with authorization of further activity until British Columbia was prepared to do so, and perhaps it is the same understanding that gives rise to references to an alleged annual letter from an unidentified federal official to licenseholders assuring that a lack of activity would not jeopardize their licenses.

Telephone conversation with an official in the Frontier Lands Management group of Natural Resources Canada, which is responsible for the administration of the federal offshore lands, confirms that in fact the present situation is simply the policy of the Minister that the Department will not entertain applications for new licenses, or for work under existing licenses, and has relieved existing licenseholders of their responsibility to undertake the work obligations normally present as a condition of holding a license. Initially this exemption from work requirements had to be extended and confirmed annually; under present regulations this is no longer the case. A decision by the Minister to initiate a land sale, or to invite companies to renegotiate existing licenses, would effectively end the federal moratorium. But it is the policy of the federal government not to initiate such measures without the concurrence of the provincial governments concerned.

Thus the administrative history of the federal moratorium seems somewhat cloudy: it is not clear that any single piece of paper exists to establish or describe the federal moratorium. There is a straightforward process to repeal an Order in Council if one existed. Though there seems clearly to be a policy, it is not yet clear whether any explicit policy statement exists. Spokespeople for Environment Canada insist, and Minister Anderson confirms, that his position is clear: If there were a concrete site-specific proposal advanced, it would have to meet all the stringent requirements of the existing legislation as to environmental assessment and review, including the responsibility to prepare all the studies necessary to such a review, but there would be no bar to consideration of such a proposal. New proposals could be submitted, in other words, through the relevant review procedures, which themselves would have the task of establishing that the proposed activity would not have unacceptable environmental or social impacts.

The case in British Columbia is also somewhat ambiguous. As noted above, a 1982 Order in Council defined a provincial Inland Marine Zone and established regulations banning drilling in it (Reg 10/82). Following the extensive 1986 review of Chevron's proposals for a program of exploratory drilling, consideration was given to lifting that prohibition, but the Nestucca Barge and Exxon Valdez oil spills intervened. The Province announced in 1989 that there would be no drilling for at least five years.

In 1994, a new Order in Council (OIC 248) and a new regulation (55/94) revised Regulation 10/82, dropping Note 2 to Schedule 2. And so, it seems, any formal prohibition on drilling offshore ended. Presumably British Columbia now could simply declare that there is no moratorium, that the provincial government is also willing to consider applications under the existing legislative and regulatory regime.

It thus appears that the moratoria could be 'lifted' either actively, as a positive decision by either government, or by implication, simply by federal and provincial governments indicating a willingness to entertain new applications for exploratory activity under the existing regulatory regime, or new applications for licenses to undertake such activity. It appears inevitable that any such application would trigger both the Canadian Environmental Assessment Act and the BC Environmental Assessment Act (as discussed below).

As noted above, to bring clarity to the regulatory regime under which oil or gas exploration or development would proceed, there would have to be mutual agreement in bilateral discussions, with a comprehensive accord on commitments to a process for environmental review, perhaps with mirror legislation governing administration, regulation and environmental review, perhaps with some new Joint Board, perhaps involving augmented responsibilities assumed by British Columbia's existing Oil and Gas Commission. Such an accord must also address resolution of First Nations claims and concerns.

In the case of British Columbia, major questions about resource revenue sharing with aboriginal communities will have to be addressed along with federal-provincial accords on resource revenues, in negotiations separate from any required environmental reviews. The potential difficulty of any such negotiations might be illustrated by the fact that the National Round Table on the Environment and the Economy was unable to find any consensus around the 'free entry' provisions applying to mineral rights in the North West Territory. (See the State of the Debate report on Aboriginal Communities and Non-Renewable Resource Development, NRTEE, 2001, which also provides useful illustrations of provisions for equity participation by aboriginal communities, employment guarantees and similar provisions related to economic benefits, all features of the approval processes and operational procedures now in place on the East Coast.)

In negotiating a Pacific Accord, there are some other lessons to be learned from recent experience in Atlantic Canada. First, on design issues, the Government of Nova Scotia in November 2001 introduced legislation to separate the industry promotion responsibilities of the Offshore Board from potentially conflicting responsibilities for health, safety and environmental integrity. Second, on resource sharing questions, it obviously will be necessary to take into account the interactions with other features of fiscal federalism, particularly the workings (in BC, the non-workings) of the Equalization Program.

Appendix 4: Definitions Scientific/Technical Methods Related to Offshore Exploration[2]

"Geophysical" work involves the indirect measurement of the physical properties of rocks in order to determine the depth, thickness, structural configuration or history of deposition and includes the processing, analysis and interpretation of material or data obtained from such work. Specific geophysical operations measure or investigate, by indirect methods, the subsurface of the earth for the purpose of locating petroleum or of determining the nature of the seabed and subsurface conditions at a proposed drilling site or of a proposed pipeline route, and include seismic surveys, resistivity surveys, gravimetric surveys, magnetic surveys, electrical surveys, geochemical surveys, and any work preparatory to that measurement or investigation, such as field tests of energy sources, calibration of instruments and cable ballasting, but do not include a velocity survey or a vertical seismic survey that is not a walkaway vertical seismic survey.

"Geological" work is defined as work, in the field or laboratory, involving the collection, examination, processing or other analysis of lithological, paleontological or geochemical materials recovered from the seabed or subsoil of any portion of the offshore area and includes the analysis and interpretation of mechanical well logs.

"Geotechnical" work is defined as work, in the field or laboratory, undertaken to determine the physical properties of materials recovered from the seabed or subsoil of any portion of the offshore area (dealt with further in Chapter 4 of this Review).

"Environmental" study is defined as work pertaining to the measurement or statistical evaluation of the physical, chemical and biological elements of the lands, oceans or coastal zones, including winds, waves, tides, currents, precipitation, ice cover and movement, icebergs, pollution effects, flora and fauna both onshore and offshore, human activity and habitation of any related manners.

Marine multichannel and high-resolution single channel seismic surveys have been used to understand the structure and basic stratigraphy of BC offshore basins, fault structures and other relevant features. **Gravity and magnetic** surveys and studies have been used for the development of geological and tectonic models. **Geothermal** studies provide data for crustal temperatures, tectonic models, and basin organic maturation. **Structural and geochemical** studies of Tertiary volcanic rocks contribute to an understanding of the tectonic origin and formation of basins, their subsidence and uplift, and tectonic associations with plate interactions along subduction zones and transform faults such as the Queen Charlotte Fault. **Seismic monitoring** of earthquakes is essential for understanding seismic hazards. The Queen Charlotte Basin and margins are particularly complicated and have been subjected to all of these techniques and disciplines. Given that the QCB has been recognized as the area with greatest potential for offshore oil and gas, it commands the greatest attention in this review.

Multi-beam Swath Bathymetry is the current state of the art technology for determining seafloor morphology and characterization. That is, it provides an indication of materials present on the ocean bottom, including bedrock, sediment distribution, and by extension and interpretation, areas of more or less risk from submarine slumping, liquefaction, turbidity currents, etc. Other techniques, such as **side-scan sonar, sub-bottom profiling and sampling** are routinely incorporated into the final interpretation. Surveys have been done for selected areas of the BC offshore, most locations being driven by population centres which might be most at risk from related hazards such as disruption of communications or pipelines. These surveys are done in cooperation with the Canadian Hydrographic Service, and cost about $100,000 per month, with e.g. a ~60x60 km map requiring three months. **Open File 2195** is a 1:250,000 scale interpretation of possible geoscience seafloor hazards in Hecate Strait/Queen Charlotte Sound. Larger scale (1:50,000, 1:20,000) interpretations will require substantially more data except in selected areas such as the sponge complexes which have been studied in some detail.

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[2] Many entries are taken from Canada-Newfoundland Offshore Petroleum Board.

Earthquake Monitoring (Based on interview with Dr. Gary Rogers, Geological survey of Canada)

It's very clear that the science for understanding earthquakes is highly sophisticated world-wide, and for the BC offshore fairly advanced in specific terms. Prior to 1970 there were no seismographs on Queen Charlotte Islands, only one until the mid-80s when twelve were installed. Although six were removed during the down-sizing of 1996, the remaining six still leave QCI fairly well-instrumented, given that there are only ~100 in all of Canada. Using more distant seismographs, the catalogue of potentially damaging earthquakes in the region, those of magnitude 6 or greater, is complete since 1917. Nevertheless, we can't fail to compare the small number of nine QCI seismographs with the 700 deployed in the analogous region of California.

There is a fundamental distinction between the deterministic, or site-specific knowledge of earthquake hazards, and the broader-based probabilistic understanding. The earthquake hazard in the Queen Charlotte region has been determined and is published in the Geological Survey of Canada's national seismic hazard maps. These hazard maps are used to define engineering design criteria for the National Building Code, and to provide information for preliminary design criteria for specialized structures. The ongoing research for the next generation hazard maps indicates that there will be no increase in seismic hazard in the Queen Charlotte Islands region over the present maps.

The Canadian Standards Association has design standards for offshore structures (A Preliminary Standard S471-M1989 B **GENERAL REQUIREMENT: DESIGN CRITERIA, THE ENVIRONMENT, AND LOADS, Part 1 of the code for the Design, Construction, and Installation of Fixed Offshore Structures@** - ISSN 0317-7874; published in May 1989 by Canadian Standards Association). These standards are currently undergoing review to be consistent with the format of the next generation seismic hazard maps. Regulators may require more detailed seismological or geotechnical investigations to define final engineering design criteria for structures associated with offshore production.

Appendix 5: Offshore Oil and Gas Approvals in Atlantic Canada[3]

Offshore Oil and Gas Approvals in Atlantic Canada
A guide to regulatory approval processes
for oil and natural gas exploration and production
in the Newfoundland Offshore Area
June 2001

The Regulatory Roadmaps Project

Erlandson & Associates Consultants

The preparation of this Guide was undertaken jointly by the Atlantic Canada Petroleum Institute, and Erlandson & Associates Consultants, Victoria, British Columbia.
Written and compiled by Reade Davis in St. John's, Newfoundland, with assistance from Gloria Chao in Halifax, Nova Scotia.

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[3] Because of the importance of the approval process that relates to offshore exploration in other jurisdictions, the Panel has reproduced here the Table of Contents for *Offshore Oil and Gas Approvals in Atlantic Canada*, as well as several schematic diagrams outlining specific steps at each stage of an offshore program.

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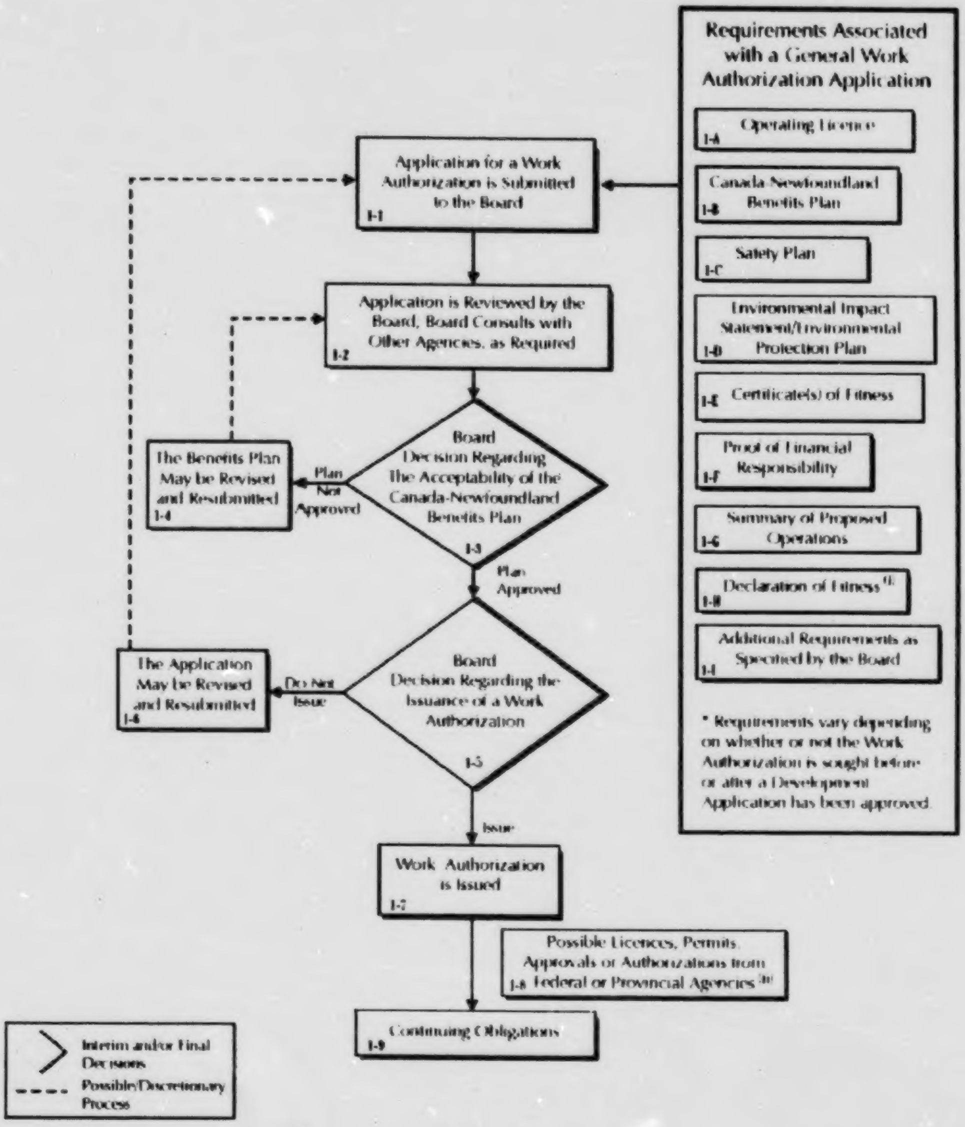
CHART 1 - Newfoundland Offshore CNOPB's General Work Authorization Process June 2001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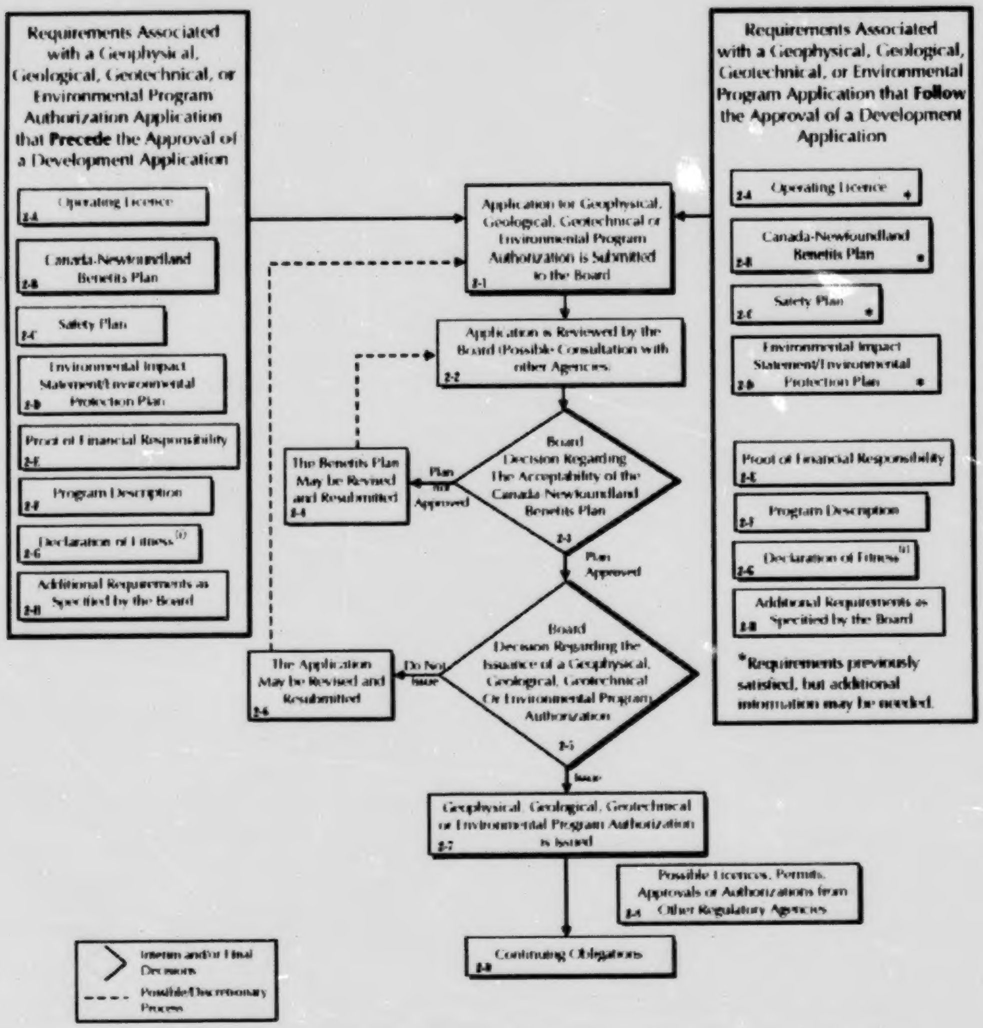
Continuing Obligations 1-9
Interim and/or Final Decisions
Possible/Discretionary Process

(i) In practice, the Declaration of Fitness is only submitted to the Board when all other requirements have been fulfilled.

(ii) Provincial authorizations may be required in a circumstance where there is bridging of offshore and onshore activities.

CHART 2 - Newfoundland Offshore Geophysical, Geological, Geotechnical or Environmental Program Authorization

June 2001


Requirements Associated with a Geophysical, Geological, Geotechnical, or Environmental Program Authorization Application that **Precede** the Approval of a Development Application
Operating Licence
2-A
Canada-Newfoundland Benefits Plan
2-B
Safety Plan
2-C
Environmental Impact Statement/Environmental Protection Plan
2-D
Proof of Financial Responsibility
2-E
Program Description
2-F
Declaration of Fitness (i)
2-G
Additional Requirements as Specified by the Board
2-H
Application for Geophysical, Geological, Geotechnical or Environmental Program Authorization is Submitted to the Board
2-1
Application is Reviewed by the Board (Possible Consultation with other Agencies)
2-2
Board Decision Regarding The Acceptability of the Canada Newfoundland Benefits Plan
2-3
Plan not Approved
The Benefits Plan May be Revised and Resubmitted
2-4
Plan Approved
Board Decision Regarding the Issuance of a Geophysical, Geological, Geotechnical Or Environmental Program Authorization
2-5
Do Not Issue
The Application May be Revised and Resubmitted
2-6
Issue
Geophysical, Geological, Geotechnical or Environmental Program Authorization is Issued
2-7
Possible Licences, Permits, Approvals or Authorizations from Other Regulatory Agencies
2-8
Continuing Obligations
2-9
Requirements Associated with a Geophysical, Geological, Geotechnical, or Environmental Program Application that **Follow** the Approval of a Development Application
2-A Operating Licence *
2-B Canada-Newfoundland Benefits Plan *
2-C Safety Plan *
2-D Environmental Impact Statement/Environmental Protection Plan *
Proof of Financial Responsibility
2-E
Program Description
2-F
Declaration of Fitness (i)
2-G
Additional Requirements as Specified by the Board
2-H
*Requirements previously satisfied, but additional information may be needed.
Interim and/or Final Decisions
Possible/Discretionary Process

(i) In practice, the Declaration of Fitness is only submitted to the Board when all other requirements have been fulfilled.

Appendix 6: Geologic Situation and Hydrocarbon Potential of Queen Charlotte Basin[4]

Introduction

The Queen Charlotte Basin (QCB) between the BC mainland and the Queen Charlotte Islands is expected to have substantial petroleum accumulations (Figure 1). Speculative estimates of the oil in place center around 1.5 billion cubic meters (m^3) or 9.8 billion bbl (e.g, Hannigan et al., 1998). They estimate natural gas in place to be around 730 billion cubic meters (m^3) or 26 Tcf. Recoverable reserves are lower possibly 400 million cubic meters (m^3) or 2.5 billion bbl oil and 550 billion cubic meters (m^3) or 20 Tcf gas (Tables 1 and 2).

Queen Charlotte Basin Region

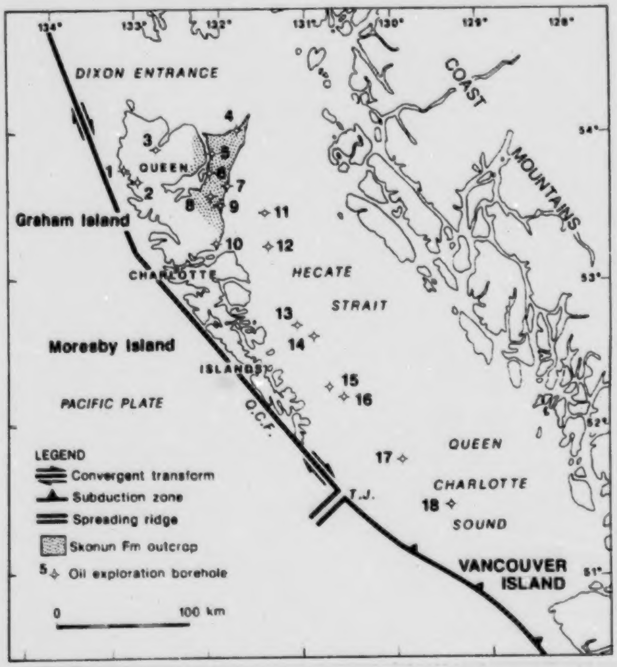

134°
133°
132°
131°
130°
129°
128°
DIXON ENTRANCE
COAST
MOUNTAINS
54°
53°
52°
51°
QUEEN
CHARLOTTE
ISLANDS
Graham Island
Moresby Island
HECATE
STRAIT
PACIFIC PLATE
Q.C.F.
T.J.
QUEEN
CHARLOTTE
SOUND
VANCOUVER
ISLAND
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
LEGEND
Convergent transform
Subduction zone
Spreading ridge
Skonun Fm outcrop
5 Oil exploration borehole
0
100 km

Figure 1. Location map of Queen Charlotte Basin (Hecate Strait) showing the major tectonic features and 18 previous drillhole locations (from Woodsworth, 1990)

Based on National Energy Board figures, these potential oil and gas resources are significant on a national scale as shown in Tables 1 and 2. However, whether or not these estimates are realistic will require considerably more exploration effort.

Table 1. Comparison (Discovered Marketable Resources)

Location	Oil (10^6 m^3)	Natural Gas (Tcf)
QCB	400*?	20*?
A. Canada	4,555	198
B. WCSB	2957	159

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[4] Submission to Dr. D.S Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

C. Frontier	528	33
D. BC conventional	129	20

*? = Speculative estimation

Table 2. Comparison (Ultimate Resources)

Location	Oil (10^6 m^3)	Natural Gas (Tcf)
QCB	730*?	26*?
A. Canada	9,177	733
B. WCSB	3,623	335
C. Frontier	4,255	303
D. BC conventional	184	50

*? = Speculative estimation

The QCB is the largest Tertiary basin on Canada's West Coast. It represents an area of approximately 80,000 km^2 (500 km long, 150 - 200 km wide) containing:

1. Queen Charlotte Islands;
2. Offshore areas of Hecate Strait
3. Queen Charlotte Sound
4. Dixon Entrance

The QCB is bounded to the south and north by Vancouver Is. and Alaska. It is terminated to the east by the Coast Plutonic Complex and to the west by the large Queen Charlotte Fault that separates the North American Plate from the Pacific Plate (Figure 1, from Woodsworth, 1990).

To date, 18 exploration wells have been drilled (shown in figure) in the QCB, with 8 offshore in the Hecate Strait and 10 on Graham Island. These wells, combined with the regional geophysical seismic studies and land-based geology are the basis of the prospectivity projections. Estimates are based on abundant reservoir strata, presence of potential source rocks, numerous structural traps, and common occurrence of oil and gas shows.

The Neogene portion of the Queen Charlotte Basin is expected to contain 80% of region's total petroleum resource volume and nine of the ten largest fields. Geographically speaking, most prospective areas are southern Hecate Strait, followed by Queen Charlotte Sound, eastern Graham Island, northern Hecate Strait and Dixon Entrance (Figure 1). High potential for southern Hecate Strait based on abundant Neogene reservoir strata, numerous large structural features, and presence of Neogene and Jurassic source rocks. Outside the basin margins, western Graham Island and adjacent shelf areas have some potential targets, but very little petroleum potential is expected overall in the onshore/inter-island areas of the southern Queen Charlotte Islands and adjacent Pacific continental shelf.

Basic Stratigraphic Sequence – Key Geologic Units

The QCB is termed a Tertiary Basin, i.e., younger than 65 Ma, but in fact some of the more interesting geologic unit are older. The basic stratigraphic framework is shown in Figure 2 (from Dietrich, 1995) and in Table 3.

The so-called basement of the basin, i.e., the floor unit for any expected petroleum formation and occurrence, is the several thousand meters of volcanics comprising the Triassic Karmutsen Formation (Ladinian-Carnian age, ca. 230 Ma, up to 4,600m thick)

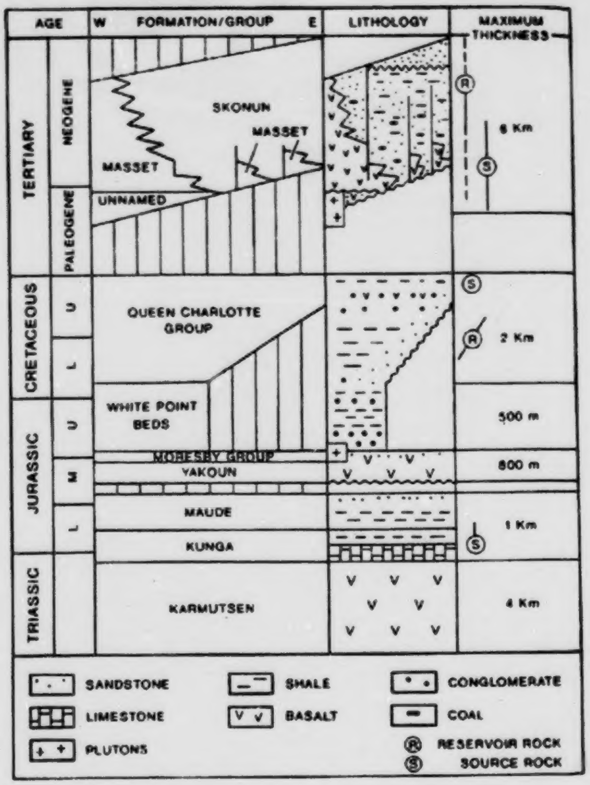
AGE
W
FORMATION/GROUP
E
LITHOLOGY
MAXIMUM THICKNESS
TERTIARY
NEOGENE
PALEOGENE
SKONUN
MASSET
MASSET
UNNAMED
R
S
6 Km
CRETACEOUS
U
L
QUEEN CHARLOTTE GROUP
S
R
2 Km
JURASSIC
U
M
L
WHITE POINT BEDS
500 m
MORESBY GROUP
YAKOUN
800 m
MAUDE
KUNGA
S
1 Km
TRIASSIC
KARMUTSEN
4 Km
SANDSTONE
SHALE
CONGLOMERATE
LIMESTONE
BASALT
COAL
PLUTONS
R RESERVOIR ROCK
S SOURCE ROCK

Figure 2. Geological stratigraphic sequence of Queen Charlotte Basin (from Dietrich, 1995)

The Karmutsen strata are overlain by up to 600m of Upper Triassic and Lower Jurassic limestones, sandstones, and shales of the Kunga groups (Carnian-Norian-Hettangian age, ca. 200-225 Ma). This is followed by 300m the deep marine, shale to siltstones, sandstones with mudstones of the Lower Jurassic Maude Gp (Sinemurian, Pliensbachian, Toarcian, ca. 185-200 Ma). These shallow to deep marine rocks Kunga and Maude Gp are some of the best oil prone potential source rocks in the region.

These Lower Mesozoic successions are uncomformably overlain by several hundred meters of volcanic and volcaniclastic rocks of the Middle Jurassic Yakoun and Moresby groups (Aalenian-Tithonian, ca. 144-185 Ma, 1000m). Uncomformably overlying these groups are up to 2500m of Upper Jurassic-Cretaceous sandstone-shale-conglomerate of the Longarm Fm (Berriasian through Aptian, ca. 98-144 Ma, 450 m) and Queen Charlotte Group (Albian through Masstrichtian, ca. 68-98 Ma, 2500 m). Selected intervals of the

Table 3. Basic Stratigraphy of Queen Charlotte Basin

L. Triassic: Ladinian, Carnian, ca. 230 Ma

Karmutsen Fm: up to 4600 m - Effective Basement

- basalts (greenstone), minor limestones, argillites

L. Triassic/E. Jurassic: Carnian, Norian, Hettangian, ca. 200-225 Ma

Kunga Gp: ca. 600 m - Source Beds

- shallow to deep marine, limestones to siltstones, argillite, tuff

E. Jurassic: Sinemurian, Pliensbachian, Toarcian ca. 185-200 Ma

Maude Gp: ca. 300 m - Source Beds

- deep marine, shale to siltstones, sandstones with mudstones

Mid/L. Jurassic: Aalenian through Tithonian, ca. 144-185 Ma

Yakoun and Moresby Gp: ca. 1000 m – poor Reservoir Rocks

- shallow, volcanics, conglomerates, sandstones, siltstones

E. Cretaceous: Berriasian through Aptian, ca. 98-144 Ma

Longarm Fm: ca. 450 m – limited Reservoir Rocks

- shelf, hard sandstones to soft sandstones, shale conglomerates

Mid/L. Cretaceous: Albian through Masstrichtian, ca. 68-98 Ma

Queen Charlotte Gp: Haida, Skidegate, Honna & unnamed Fm

- ca. 2500 m – limited Reservoir Rocks

- sandstones, siltstones, mudstones, conglomerates, volcanics

E. Tertiary: Paleogene, ca. 23.7-66.4 Ma

Unnamed volcanics/flows and sedimentary rocks: ca. 1000 m

- subareal, marine – limited Reservoir Rocks

- shallow basalts, andesites, conglomerates, black shale, sandstones

L. Tertiary: Neogene, ca. 1.6-23.7 Ma

Masset Fm: up to 4,000 m, basalts, rhyolite flows, pyroclastics

- marine and terrestrial – good Reservoir Rocks

Skonun Fm: ca. 5,000 m - sandstones, shale, conglomerates, lignite

- marine and terrestrial– good Source and Reservoir Rocks

Queen Charlotte Group have good reservoir characteristics, the most promising being shallow-marine sandstones and granule conglomerates in basal part of the formation.

These strata were deposited along NW-SE paleo-shorelines in the Queen Charlotte Islands and western parts of Dixon Entrance, Hecate Strait, and Queen Charlotte Sound (Haggart, 1991; Lyatsky and Haggart, 1993). Fogarassy and Barnes (1991) described outcrop reservoir characteristics with porosity averaging 5 to 10%, and permeability considered fair to good.

The lower Tertiary rocks (Paleogene, ca. 23.7-66.4 Ma) are largely unnamed volcanics/flows and sedimentary units. These ca. 1000 m subareal and marine rocks have components of conglomerates, black shale, sandstones giving them a limited reservoir quality. The Neogene (1.6-23.7 Ma) volcanic and sedimentary rocks of the Masset and Skonun formations (respectively) unconformably overly the Paleogene and older successions. The marine and terrestrial Masset Fm is comprised of up to 4,000 m, basalts, rhyolite flows, and pyroclastics. These represent good reservoir rocks. The Skonun consists of interbedded sandstone, shale, conglomerate and lignite (coal), up to 6 km thickness offshore. This contains the primary petroleum exploration targets, with sandstone porosities between 25 to 35% (>2000m), and fair to very good permeability (10 to 1500md) (Dietrich, 1995). At depths of 2000-3000m porosity decreases by 5%, with fair permeability (10 to 100md). Below 3000m, reservoir potential is minimal due to low permeability.

Basic Structural Framework

The QCB is within the tectonic province called the Insular Belt. As noted, the basement of this Tertiary extensional syn- and post-rift type basin is the Wrangellia supracrustal terrane. The main structural features within the Queen Charlotte Basin developed in association with Miocene transtensional and Plio-Pleistocene transpressional tectonics.

The QCB is characterized by 4 Paleozoic - Cenozoic tectonostratigraphic divisions, namely:

1. Permian - mid Jurassic,
2. Mid - Late Jurassic
3. Cretaceous
4. Tertiary

The L. Triassic/E. Jurassic (Karmutsen Fm, Kunga Gp, Maude Gp) are comprised of intraoceanic and island/back-arc rocks of Wrangellia Terrane. These are typical of a back-arc rifting, allochthonous to N. America plate. The Mid/L. Jurassic (Yakoun Gp and Moresby Gp) contain the San Christoval and Burnaby Island Plutonic Suites. The structural components are discrete NW dip-slip faults with uplifted tectonic blocks. The Cretaceous (Longarm Fm and Queen Charlotte Gp) can be characterized by block faulting and relatively long wavelength NW-trending folds (λ ca. 0.5 - 1.5 km).

The Tertiary (Paleogene, Masset Fm and Skonun Fm) structural unit has active steep NW, N and ENE faults (sinistral strike-slip). The extensively fault-controlled basin development has created a complex assemblage of graben and half-graben fills highly variable in thickness and with compressional inversions and deformation (Rohr and Dietrich, 1992). Miocene structures include north and northwest aligned normal and oblique slip faults. Pliocene structures include reverse faults (often a result of inversions of Miocene normal faults), contractional folds and combination fault-fold flower structures. Pleistocene structures are local folds and tilted, truncated Neogene strata. In relation to structures forming potential traps for petroleum accumulation, Table 1 shows the variety of both structural and stratigraphic traps that may occur within the basin. It is important to note that Pliocene traps are restricted to northern Hecate Strait and Dixon Entrance. Stratigraphic traps may also be locally present in shallow parts of the Queen Charlotte Basin where tilted Neogene strata are unconformably overlain by Quaternary mudstones.

Table 4. Paleozoic - Cenozoic Tectonostratigraphic Divisions

L. Triassic/E. Jurassic

- Karmutsen Fm, Kunga Gp, Maude Gp
  - intraoceanic and island/back-arc rocks of Wrangellia Terrane
  - back-arc rifting, allochthonous to N. Am plate.

Mid/L. Jurassic

- Yakoun Gp and Moresby Gp
  - San Christoval and Burnaby Island Plutonic Suites
  - discrete NW dip-slip faults with uplifted tectonic blocks

Cretaceous

- Longarm Fm and Queen Charlotte Gp
  - block faulting, NW folds (λ ca. 0.5 - 1.5 km)

Tertiary

- Paleogene, Masset Fm and Skonun Fm
  - active steep NW, N and ENE faults (sinistral strike-slip)
  - fault controlled basin development (graben and half-graben fills)
  - compressional inversions and deformation

Source Rock Potential

The offshore deepest wells in the Hecate Strait of the Queen Charlotte Basin have penetrated only the uppermost Cretaceous, so the deeper source rock information is speculative. Basically, the source rocks in the QCB are either older oil prone Type I/II kerogens or younger gas prone Type III kerogens.

Source rock distribution is considered to be highly irregular due to episodic erosion events from Middle Jurassic through Tertiary time. Kunga-Maude strata are most likely preserved in the southwestern part of the basin beneath Graham Island and western parts of Dixon Entrance, Hecate Strait and Queen Charlotte Sound (Thompson et al., 1991; Lyatsky and Haggart, 1993). Upper Kunga limestones and argillites and lower Maude shales contain oil source rocks with Type I and Type II organic matter. Total Organic Carbon (TOC) averages 1 to 4 wt % in sections up to several hundred meters thick. If Late Jurassic through Tertiary block faulting occurred offshore as well as onshore, erosion could have potentially removed source strata from some areas, especially adjacent to the eastern side of Southern Moresby Island (Thompson et al., 1991). In some offshore areas, carbonaceous beds and coal seams in non-marine Upper Cretaceous strata may have some gas potential. Skonun formation strata contain coal beds and dispersed type III organic matter (Figure 3). Organic content ranges from 0.5 to 1.5 wt % with higher TOC (up to 25%) in coal beds. Skonun shales and siltstones locally contain type II organic matter with up to 2.5% TOC (Vellutini and Bustin, 1991). Coal beds are more abundant in the northern half of the Queen Charlotte Basin.

Kunga-Maude rocks are overmature on the southwestern Queen Charlotte Islands, and marginally mature to mature on central and northern parts of the islands. Maturation of Kunga-Maude strata in offshore areas is unknown, but is expected to vary from mature to overmature. Model predicted profiles for the two Sockeye wells (B-10, E-66) indicate that these strata will be overmature at B-10 and mature to overmature at E-66. For the Sockeye area and many parts of central Hecate Strait most source rocks will be within oil window at depths above 3000m. Neogene strata are immature to mature with 30-40% of total basin fill falling within the oil or gas generation window. Depth to the top of the oil window typically occurs at 2000-2500m. Onshore, Macauley (1983) showed Kunga-Maude sediments that are within oil-generating phase in the Ghost Creek-Rennell Junction areas of the Skidegate Plateau, but are overmature westerly at Shields Bay and southerly at Maude Island, both along the easterly front of the Queen Charlotte Ranges.

Oil shale potential is limited to the Ghost Creek area. Both Kunga and Maude formations have generated oil, and hydrocarbon yields from organic-rich beds in the central Queen Charlotte Islands are up to 50 to 100mg HC/g rock, with excellent oil source capability. These strata are a potential source for oil accumulations below the Tertiary Masset volcanics in the Charlotte lowlands of northeastern Graham Island and under Hecate Strait.

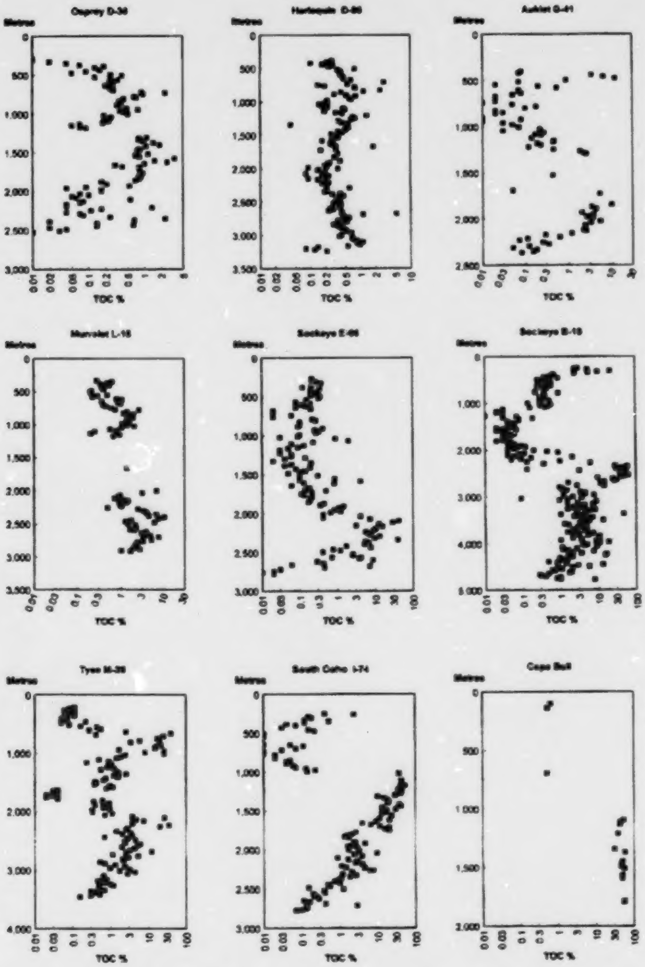

Figure 3. Total Organic Carbon (wt % TOC) depth distributions in QCB wells (from Bustin, 1997).

Bustin (1997) analyzed TOC in offshore wells drilled by Shell Canada in the late 1960's, and found variations with depth that compliment a biparite stratigraphy developed by Higgs (1991) (Figure 3). Unit 1 is comprised mainly of middle Eocene to middle/late Miocene age syn-rift deposits, greater than 5km in thickness (mostly Skonun Fm). Unit 1 includes marine and non-marine clastics (sandstone, mudstone, coal and pebble conglomerates) and volcanics in predominantly northwest and less commonly east or northeast trending grabens and half-grabens. This unit is draped by marine and non-marine post-rift strata up to 2 km in thickness of early Miocene to Quaternary age sediments termed Unit 2. The base of Unit 2 was chosen to distinguish a distinct change in log character, whereby most logs become erratic due to the presence of coal interbeds.

TOC showed a systematic "S shaped" variation in six wells (D-36, G-41, B-10, E-66, N-39, I-74) ranging from 0.5 wt. per cent at the base of Unit 1 to almost 30 per cent near the contact of Unit 1 and 2 (Figure 3). Bustin (1997) attributed this with a shift from predominantly non-marine strata of Unit 1 to transitional marine–non-marine strata of Unit 2. TOC declines to 0.5 per cent in the middle of Unit 2, only to increase back to 30 per cent in all wells except E-66 near the surface. The N-39 and D-36 wells show a decline in TOC towards the surface. Other wells (D-86 and L-15) showed no clear trend for TOC. The increase to the top of Unit 2 and the lack thereof in other wells was interpreted as either a decrease in clastic sedimentation rate (hence dilution of organic matter), or a progressive decrease in transitional marine and increase in non-marine strata. Bustin (1997) noted that neither well logs nor biostratigraphy could definitively resolve the trends observed in TOC content. Kerogen types are mostly type III, with exception of B-10 having some type II. There is poor correlation between TOC and hydrogen index (HI) values. No stratigraphic trend for TOC or HI was evident in any onshore wells examined, most likely due to limited data.

Bustin (1997) also noted that an increase in the pristane/phytane ratio with depth in some wells can be interpreted as a greater abundance of terrestrially derived organic matter. The abundance of organic matter and to a lesser degree source rock quality closely follows the biparite stratigraphy in the offshore wells. Depth to the top of the oil window (Figure 3) follows the gross stratigraphy (Unit 1) more closely than depth of burial of the strata, from only 500m on Graham Island to more than 3000m in Queen Charlotte Sound (Tyee and South Coho excepted). Depth to the base of the window and thickness of strata in the window is strongly controlled by maturation gradients and paleoheat flows (i.e. steeper the gradient, less strata within the window). Tyee N-39 and Sockeye E-66 contain the thickest successions within the oil window. Basin modeling using a modified McKenzie model shows timing of peak hydrocarbon generation is also highly variable in offshore wells. Unit 1 in South Coho has yet to reach peak generation, while Sockeye wells passed this stage 20 my ago. In most wells (B-10, E-66, L-15, G-41, D-36) the base of Unit 1 reached an oil generative stage between 9 and 16 Ma. The base of Unit 2 has not reached oil generation phase in D-86, M-36 and I-74, but in other offshore wells this occurred between 7 and 20 Ma and currently remains in the oil window.

Table 5. Summary of Source Rocks in the Queen Charlotte Basin

1. L. Triassic/E. Jurassic Source Rocks
    - Kunga Gp: ca. 600 m
        - shallow to deep marine, limestones to siltstones, argillite, tuff
    - Maude Gp: ca. 300 m
        - deep marine, shale to siltstones, sandstones with mudstones
        - good late/over-mature oil and gas prone (Type I/II) source rocks
        - only information from onshore outcrop and shallow drill
2. Cretaceous Source Rocks
    - Longarm Fm and Queen Charlotte Gp
        - sandstones, shales, conglomerates, mudstones, volcanics
        - minor coal-bearing, non-marine intersections reported at base of Tyee, Sockeye B-10, E-66 wells.
        - very marginal, late/over-mature gas prone (Type III) source rocks
        - limited offshore and onshore outcrop and shallow drill information
3. Tertiary Source Rocks
    - Paleogene - basalts, andesites, conglomerates, black shale, sandstones
        - very marginal, mature source rocks
    - Masset Fm: up to 4,000 m, basalts, rhyolite flows, pyroclastics
        - very marginal, mature gas prone (Type III) source rocks
    - Skonun Fm: ca. 5,000 m - sandstones, shale, conglomerates, lignite
        - marginal-good, mature-late mature, gas prone Type III source rocks

Oil Shows and Seepages

Over 50 oil, tar, or natural gas seeps have been identified onshore Queen Charlotte Islands (Hamilton and Cameron, 1989) (Figure 4). Geological and geochemical analysis show seeps are migrated oils sourced from Kunga-Maude (Jurassic) and Tertiary strata (Fowler et al., 1987, Hamilton and Cameron, 1989). Seeps are widespread and exposed in roadcuts, quarries and beach outcrops, with bitumen and tar as the main products. Lawn Hill on the southeast coast of Graham Island contains one of the most areally extensive surface oil seeps, probably sourced from underlying or subadjacent Jurassic source rocks, with migration into host rocks in late Neogene time (Snowdon et al, 1988; Hamilton and Cameron, 1989). Cretaceous or Neogene reservoir strata in the surrounding or basinward areas is considered highly prospective for conventional oil accumulations. Shows at King Creek include oil staining, lighter oils, natural gas seeps and volatile petroleum hydrocarbons. Tar occurs in fractures and vesicles within thin basalt flows and agglomerates. Most shows are in Masset volcanics. King Creek shows suggested that a principal hydrocarbon source lies below a basal Tertiary unconformity in subjacent Lower Jurassic rocks (Kunga-Maude). Hydrocarbons occur in primary and secondary porosity of the Masset formation from Otard Point to the head of Otard Bay. Oil films are common on streams and pools that drain this area.

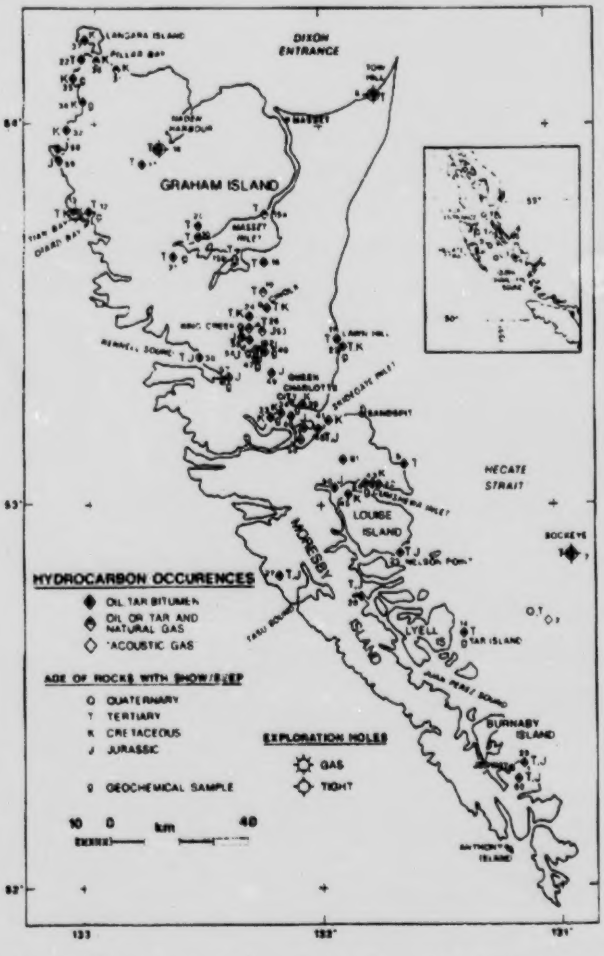
LANGARA ISLAND
DIXON ENTRANCE
GRAHAM ISLAND
MASSET
MASSET INLET
OTARD BAY
KING CREEK
RENNELL SOUND
LAWN HILL
QUEEN CHARLOTTE
SKIDEGATE INLET
SANDSPIT
HECATE STRAIT
LOUISE ISLAND
MORESBY ISLAND
LYELL IS
TAR ISLAND
BURNABY ISLAND
SOCKEYE
HYDROCARBON OCCURENCES
OIL TAR BITUMEN
OIL OR TAR AND NATURAL GAS
'ACOUSTIC GAS'
AGE OF ROCKS WITH SHOW/SEEP
Q QUATERNARY
T TERTIARY
K CRETACEOUS
J JURASSIC
GEOCHEMICAL SAMPLE
EXPLORATION HOLES
GAS
TIGHT
10 0 km 40
54°
53°
52°
133
132°
131°

Figure 4. Location of observed hydrocarbon seepages on Queen Charlotte Islands (from Hamilton and Cameron, 1989)

Subsurface shows were encountered in several wells, most notably oil staining in Neogene sandstones of the Tow Hill (onshore) and Sockeye B-10 (offshore) wells (Hannigan et al., 1998). Biomarker analysis of the saturate fraction from the Sockeye sample indicated a compound diagnostic of a Kunga source rock, as indicated in similar analyses of Kunga outcrop samples. Other geochemical characteristics of the Sockeye sample also indicated a probable derivation from carbonate rocks. The Sockeye B-10 well also had numerous shows of gas-cut mud in coal-bearing zones in Skonun and Cretaceous strata below 3000m.

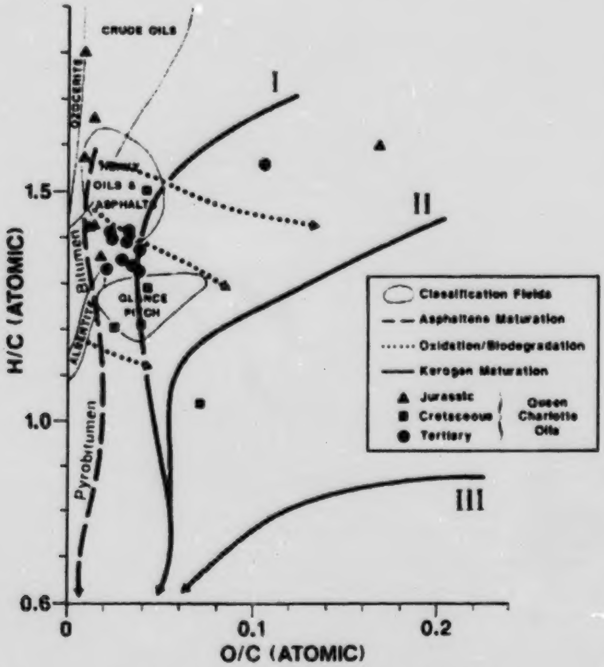

Figure 5. Bulk chemical composition of hydrocarbons recovered from seepages (from Hamilton and Cameron, 1989)

Hamilton and Cameron (1989) plotted oil show samples on a Van Krevelen diagram (Figure 5). Samples tended to group according to age. Oils did not appear to be intensely weathered. Jurassic oils had the highest H/C ratios and appeared to be the least migrated, lightest, and least viscous. Two models attempted to explain the compositional variations of these oils. Mixing models combined mature Jurassic with degraded Cretaceous source material, as Tertiary showings implied contributions from both type II (Jurassic) and type III (Cretaceous) sources. Many of the Queen Charlotte oils showed high sulfur content, indicative of a marine carbonate source (Kunga-Maude). GC analysis of King Creek and Lawn Hill oils showed low concentrations of n-alkanes below C_{20}. GC/MS data of several oils supported the concept of a dominant Lower Jurassic Type II source in Kunga-Maude strata. Variations in kerogen character complicated biomarker patterns. Trace metal abundance patterns for these oils resembled those from clastic assemblages with NaCl dominated formation waters.

Gas Shows and Seepages

Shallow gas deposits in the Queen Charlotte Basin can arise from two sources, either during early diagenesis from biogenic degradation of organic matter, or thermogenic gas diffusing upward from Tertiary bedrock. They are distributed over most of Hecate Strait and occur in most types of surficial sediments except where glacial till is at the surface

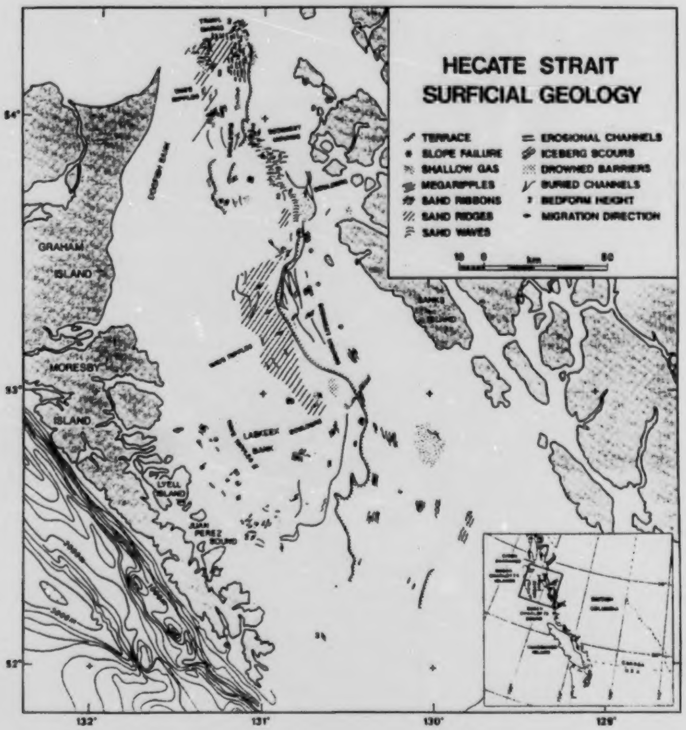
HECATE STRAIT
SURFICIAL GEOLOGY
TERRACE
SLOPE FAILURE
SHALLOW GAS
MEGARIPPLES
SAND RIBBONS
SAND RIDGES
SAND WAVES
EROSIONAL CHANNELS
ICEBERG SCOURS
DROWNED BARRIERS
BURIED CHANNELS
BEDFORM HEIGHT
MIGRATION DIRECTION
10 0 km 50
GRAHAM ISLAND
MORESBY ISLAND
LYELL ISLAND
BANKS ISLAND
54°
53°
52°
132°
131°
130°
129°

Figure 6. Surficial Geology of Hecate Strait showing surface gas locations (from Barrie, 1988)

(Barrie, 1988). Thick Holocene age silt deposits contain extensive amounts of biogenic gas. Gaseous sediments are also found along the base of underwater terraces, including the northern portion of the main trough and within the northern trough into Dixon Entrance (Figure 6). Sediments containing gas are generally near the contact of glacial till with a sand and gravel unit (Unit 3 of Barrie, 1988) and gas appears to migrate along the boundary. Gas charged sediments are also present on the western side of Hecate Strait in Unit 3 sands and areas where sands thinly cover Tertiary bedrock. Gas shows along the axis of Hecate Strait mark the western edge of a cordilleran till lobe, inferring that the till forms a cap structure (Hamilton and Cameron, 1989). Acoustic gas may indicate overmature source rocks or a different subsurface geology (gas prone). Figure 26 of Barrie (1988) shows sediment instability due to gas accumulation and a potential drilling site. Deep gas accumulations in Neogene strata have been identified on conventional seismic profiles in several offshore locations (Dietrich, 1995). An example of a direct hydrocarbon indicator is a subhorizontal low frequency at the crest of a fault bound structure. Dietrich (1995) added that several of these indicators occur at a stratigraphic level similar to the Sockeye B-10 well show.

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Appendix 7: Comparison of Queen Charlotte Basin Petroleum Situation with Other Offshore Basins[5]

1. COOK INLET (ALASKA)

The following information is extracted and reworked in part from Magoon, (1994) and Thompson et al. (1991).

Overview

Geographically, Cook Inlet on Alaska's southern coast is bordered to the northwest by the Alaska-Aleutian Range and Talkeetna Mountains, and the Kenai Peninsula-Kenai Mountains on the southeast (Figure 14). Discovery of the first field was in 1957 at Swanson River, and the subsequent history of petroleum exploration and geology in the area has been discussed by numerous studies (e.g., Magoon and Claypool, 1981; Magoon and Egbert, 1986; Magoon and Kirschner, 1990). Hydrocarbon production is from six oil fields (Trading Bay, McArthur River, Middle Ground, Granite Point, Beaver Creek, Swanson River) and three gas fields in upper Cook Inlet. Oil fields occur near the basin margin, where Tertiary reservoir rocks unconformably overlie Middle Jurassic source strata (Figure 22.3). Several accumulations are also in Oligocene-Miocene sandstones within thrust faulted Pliocene anticlines (similar to Queen Charlotte Basin).

Total petroleum resources (produced and remaining) in Cook Inlet are 2.2 Bbbl of oil and 10 Tcf of gas (Magoon and Kirschner, 1990). The largest accumulations are the McArthur River oil field (570 Mbbl) and the Kenai gas field (2.3. Tcf), both of comparable magnitude to largest fields predicted for Queen Charlotte Basin (Hannigan et al., 1998). Exploration is based on a two-part geological model of Magoon and Claypool (1981):

1) Burial and maturation of Jurassic source rocks occurred during Cretaceous and Early Tertiary, followed by updip migration of hydrocarbons into conglomerate and sandstone reservoirs of Oligocene age;
2) Hydrocarbons remobilized during Pliocene and Pleistocene deformation, filling new traps created in faulted anticlines and upturned stratigraphic pinchouts.

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[5] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

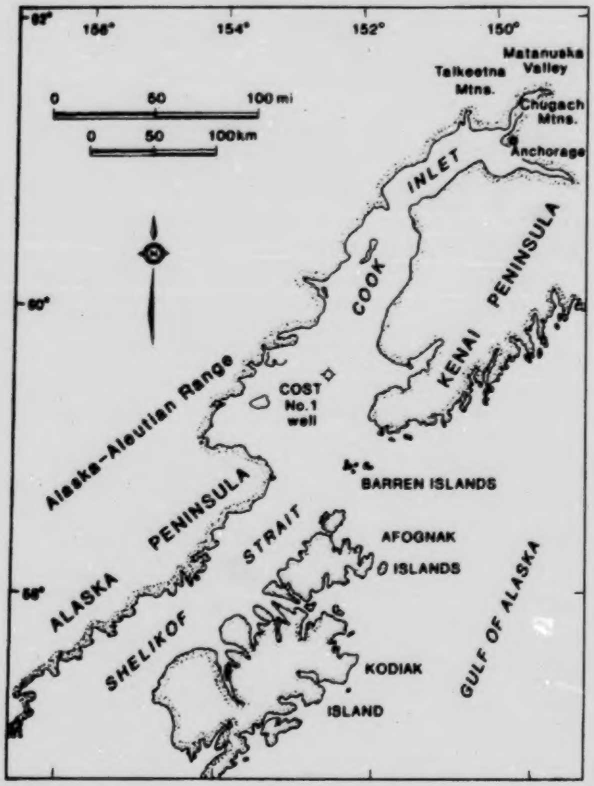
62°
156°
154°
152°
150°
Matanuska Valley
Talkeetna Mtns.
Chugach Mtns.
Anchorage
0
50
100 mi
0
50
100km
INLET
COOK
KENAI
PENINSULA
60°
Alaska-Aleutian Range
COST No.1 well
BARREN ISLANDS
AFOGNAK
ISLANDS
ALASKA
PENINSULA
SHELIKOF
STRAIT
58°
KODIAK
ISLAND
GULF OF ALASKA

Figure 14: Geography of the Cook Inlet region, Alaska (modified from Magoon and Egbert, 1986, Fig. 32).

Figure 1. Location map of Cook Inlet, Alaska, (after Magoon and Egbert, 1986

Basin History and Stratigraphy

Cook Inlet evolved from a backarc basin setting during Mesozoic time to a forearc basin in the Cenozoic. During the Mesozoic, the Aleutian Range-Talkeetna Mountain magmatic arc was active producing mainly volcanic flows and volcaniclastic sediments, as well as sand, silt, and gravel all rich in feldspar and lithic fragments. Four sequential tectonic episodes are defined by unconformities separating clastic successions from Early Cretaceous to late Cenozoic. Cretaceous strata are mostly marine while Tertiary strata are predominantly nonmarine. Cross section (Figure 22.4) shows the generalized structural style with numerous high-angle reverse faults indicating considerable compression throughout the Mesozoic and Cenozoic with minor normal faults near the Swanson River field.

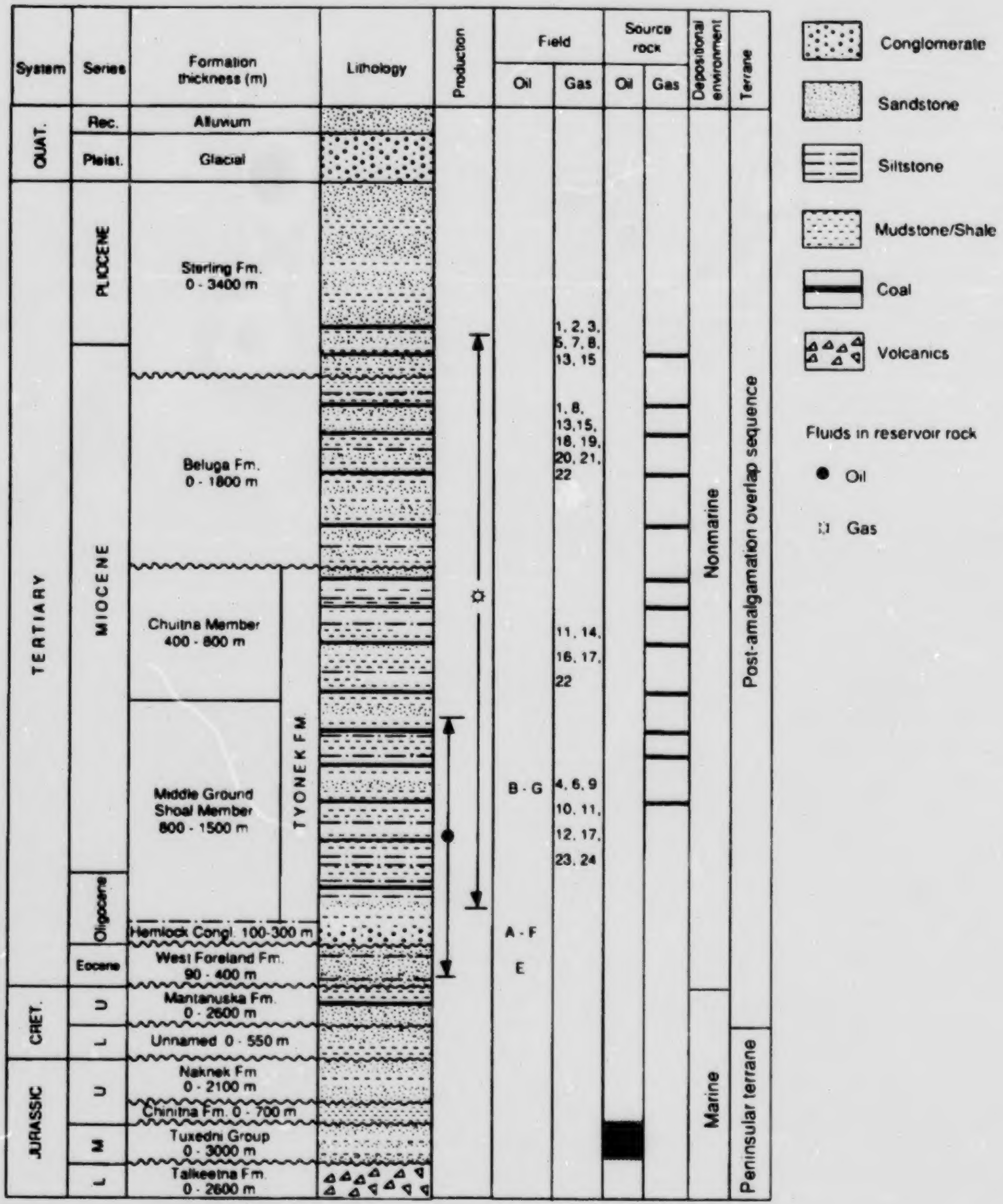
System
Series
Formation thickness (m)
Lithology
Production
Field
Oil
Gas
Source rock
Oil
Gas
Depositional environment
Terrane
QUAT.
Rec.
Alluvium
Pleist.
Glacial
TERTIARY
PLIOCENE
Sterling Fm.
0 - 3400 m
MIOCENE
Beluga Fm.
0 - 1800 m
Chuitna Member
400 - 800 m
Middle Ground Shoal Member
800 - 1500 m
TYONEK FM
Oligocene
Hemlock Congl. 100-300 m
Eocene
West Foreland Fm.
90 - 400 m
CRET.
U
Mantanuska Fm.
0 - 2600 m
L
Unnamed 0 - 550 m
JURASSIC
U
Naknek Fm
0 - 2100 m
Chinitna Fm. 0 - 700 m
M
Tuxedni Group
0 - 3000 m
L
Talkeetna Fm.
0 - 2600 m
1, 2, 3, 5, 7, 8, 13, 15
1, 8, 13,15, 18, 19, 20, 21, 22
11, 14, 16, 17, 22
B - G
4, 6, 9 10, 11, 12, 17, 23, 24
A - F
E
Nonmarine
Marine
Post-amalgamation overlap sequence
Peninsular terrane
Conglomerate
Sandstone
Siltstone
Mudstone/Shale
Coal
Volcanics
Fluids in reservoir rock
Oil
Gas

Figure 2. Statigraphic column for Cook Inlet (from Magoon, 1994)

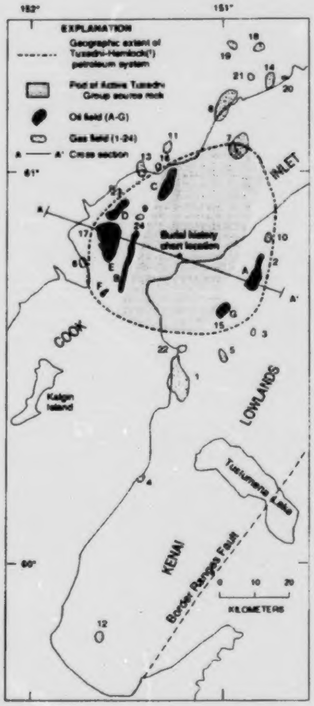
152°
151°
EXPLANATION
Geographic extent of Tuxedni-Hemlock(!) petroleum system
Pod of Active Tuxedni Group source rock
Oil field (A-G)
Gas field (1-24)
A — A' Cross section
61°
60°
A
A'
Burial history chart location
COOK
INLET
LOWLANDS
Kalgin Island
Tustumena Lake
KENAI
Border Ranges Fault
0 10 20
KILOMETERS

Figure 3 Cook Inlet oil and gas fields (from Magoon, 1994)

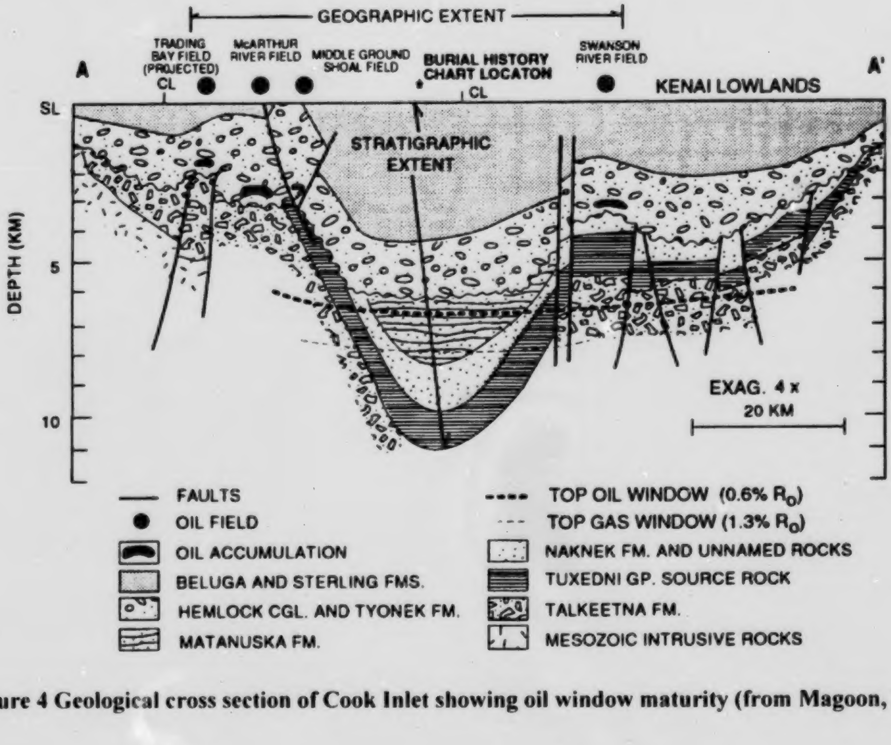
GEOGRAPHIC EXTENT
A
A'
TRADING BAY FIELD (PROJECTED)
McARTHUR RIVER FIELD
MIDDLE GROUND SHOAL FIELD
BURIAL HISTORY CHART LOCATON
SWANSON RIVER FIELD
KENAI LOWLANDS
CL
CL
SL
STRATIGRAPHIC EXTENT
DEPTH (KM)
5
10
EXAG. 4 x
20 KM
FAULTS
OIL FIELD
OIL ACCUMULATION
BELUGA AND STERLING FMS.
HEMLOCK CGL. AND TYONEK FM.
MATANUSKA FM.
TOP OIL WINDOW (0.6% R_0)
TOP GAS WINDOW (1.3% R_0)
NAKNEK FM. AND UNNAMED ROCKS
TUXEDNI GP. SOURCE ROCK
TALKEETNA FM.
MESOZOIC INTRUSIVE ROCKS

Figure 4 Geological cross section of Cook Inlet showing oil window maturity (from Magoon, 1994).

The Lower Jurassic Talkeetna Formation comprised of volcaniclastic sediments (along with the Alaska-Aleutian batholith) act as the economic basement for the petroleum province. The Tuxedni Group (dark gray, clay-rich siltstone) of Middle Jurassic age is important as the primary source rock for commercial oil deposits in the region. Upper Jurassic Naknek Formation contains a high percentage of feldspathic sandstone and conglomerate, but due to laumontite cementation is considered a poor reservoir (Bolm and McCulloh, 1986). An unconformity separates the Lower Cretaceous rocks from the Upper Cretaceous sequences, with the sandstone Matanuska and Kaguyak Formations containing little organic matter but do, in some places, act as a potential reservoir. Another unconformity separates Upper Cretaceous from Cenozoic strata. The West Foreland Formation consists of tuffaceous conglomerates to siltstones with minor amounts of coal. The Hemlock conglomerate is conglomeratic sandstone, with the Tyonek, Beluga, and Sterling formations comprised of varying amounts of sandstone, siltstone, shale and coal. Each of these rock units is a reservoir for oil or gas somewhere in the basin.

Petroleum System

The Tuxedni Group underlies most of Cook Inlet east of the Middle Ground Shoal oil field and subcrops in beneath Cenozoic strata east of Swanson River (Figure 22.4). Thickness is estimated at 1 km in the deepest part of the basin between the McArthur River and Swanson River fields. Thermal maturity of the source rock ranges from immature to mature, with TOC ranging from 2.1 wt% for immature samples to 0.9 wt% for mature samples. Based on basin modeling of Magoon (1994), the top of the oil window was reached during the Paleocene (63 Ma) and the gas window was achieved in the late Miocene (10 Ma).

Approximately 80% of recoverable oil is contained in the Hemlock Conglomerate, 20% in the Middle Ground Shoal member of the Tyonek Formation, and minor amounts in the West Foreland. Average porosity for conglomeratic sandstones is 17% (12-22%), with average permeability of 80 md (10-360 md). Seal rocks for most oil accumulations are presumed to be siltstones of the West Foreland and Tyonek Formations, and underclays associated with coals within the Tyonek Formation. Typical pools are located in faulted anticlines at average drill depths of 2560 m. A typical oil has an API gravity of 34 +/- 6 degrees, a gas-oil ratio (GOR) of 600 (175-3850), sulfur content of 0.1%.

Migration of oil is inferred based on cross sections and burial history models. Source rocks are currently within the gas window, although very little gas appears to have been generated (GOR <1000). Oil generated over the last 63 Ma has migrated updip to the flanks of the basin, and trapped stratigraphically until structural traps formed during Miocene deformation (10 Ma). Oil generated or migrated before deposition of the Hemlock Conglomerate (30 Ma) could have been lost to erosion. Based on a synclinal basin geometry, oil migrated laterally through sandstone within the source rock or in the overlying Naknek Formation to the Cretaceous-Tertiary unconformity, across the unconformity, through the West Foreland Formation and into the Hemlock Conglomerate.

A model similar to Cook Inlet may apply to the Queen Charlotte Basin. Thompson et al. (1991) noted that surface mapping showed some fault-bounded blocks have been stripped of Middle Jurassic strata, placing Triassic/Jurassic Kunga-Maude source rocks adjacent to potential Cretaceous reservoir strata. Applying this to offshore areas creates a scenario much like that in Cook Inlet, whereby source rocks are overlain unconformably by Lower Cretaceous and Tertiary sandstones (Figure 16). One could expect updip migration of hydrocarbons into overlying sandstones and possible secondary migration along the youngest set of Tertiary extension faults. Pliocene deformation in both basins has produced faulted anticlines which can constitute traps for oil and gas accumulation.

Similarities to Queen Charlotte Basin

Basins evolved in intra-arc and forearc settings

Jurassic source beds

Cretaceous and Tertiary clastics for reservoir beds

Major regional unconformities on top of Upper Jurassic/Lower Cretaceous and Upper Cretaceous sequences

Variety of type and stratigraphic distribution of oil shows (e.g. seeps)

Timing of oil generation and migration (late Tertiary, after burial of Jurassic source rocks beneath thick cover of Tertiary strata)

Traps include faulted anticlines as a result of Pliocene deformation/compression

Hannigan et al. (1998) and Dietrich (1995) also note that Mist Lake gas field in the forearc Willamette Basin of northern Oregon occurs in Eocene sandstones with compositional and reservoir characteristics of Neogene sandstones in the Queen Charlotte Basin.

Differences to Queen Charlotte Basin

Neogene tectonic/structural history. During Eocene, a regime of convergence accompanied by subduction gave way to northward transcurrent motion of oceanic plates along the continental margin replacing the forearc setting with a strike-slip margin in the Queen Charlotte region. Cook Inlet contains comparatively fewer strike-slip related extensional faults (Hannigan et al., 1998).

Source rock distribution in Queen Charlotte Basin is more sporadic due to heating associated with Middle Jurassic plutonism and uplift and erosion of source strata during Late Jurassic and Cretaceous.

Quality of seismic data for Queen Charlotte Basin is considered to be insufficient to assess the thickness, distribution, and structure of pre-Tertiary source and reservoir strata.

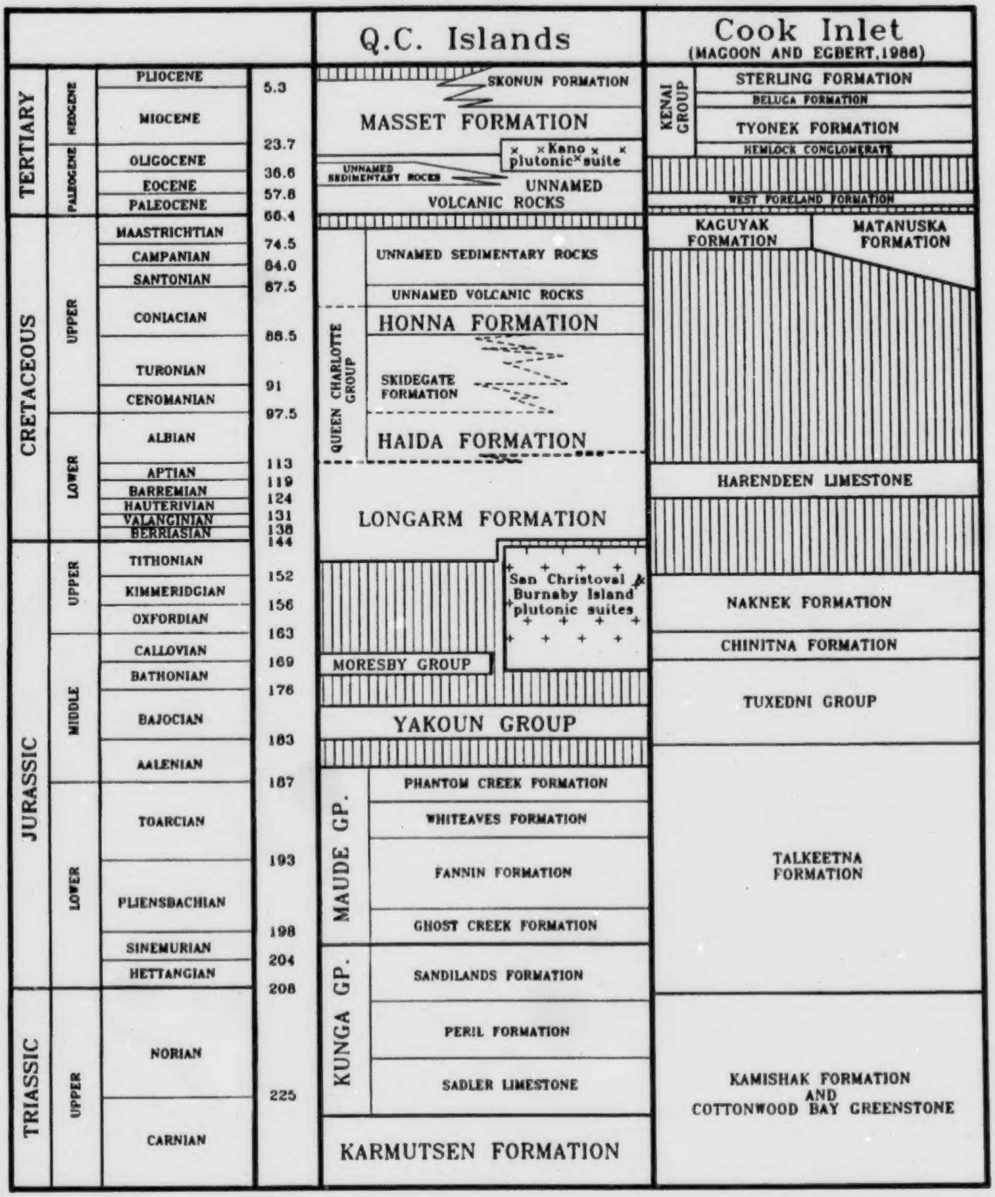
Q.C. Islands
Cook Inlet
(MAGOON AND EGBERT,1986)
TERTIARY
NEOGENE
PALEOGENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
CRETACEOUS
UPPER
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
LOWER
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
JURASSIC
UPPER
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
MIDDLE
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
LOWER
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
TRIASSIC
UPPER
NORIAN
CARNIAN
5.3
23.7
36.6
57.8
66.4
74.5
84.0
87.5
88.5
91
97.5
113
119
124
131
138
144
152
156
163
169
176
183
187
193
198
204
208
225
SKONUN FORMATION
MASSET FORMATION
Kano plutonic suite
UNNAMED SEDIMENTARY ROCKS
UNNAMED VOLCANIC ROCKS
QUEEN CHARLOTTE GROUP
UNNAMED SEDIMENTARY ROCKS
UNNAMED VOLCANIC ROCKS
HONNA FORMATION
SKIDEGATE FORMATION
HAIDA FORMATION
LONGARM FORMATION
San Christoval & Burnaby Island plutonic suites
MORESBY GROUP
YAKOUN GROUP
MAUDE GP.
PHANTOM CREEK FORMATION
WHITEAVES FORMATION
FANNIN FORMATION
GHOST CREEK FORMATION
KUNGA GP.
SANDILANDS FORMATION
PERIL FORMATION
SADLER LIMESTONE
KARMUTSEN FORMATION
KENAI GROUP
STERLING FORMATION
BELUGA FORMATION
TYONEK FORMATION
HEMLOCK CONGLOMERATE
WEST FORELAND FORMATION
KAGUYAK FORMATION
MATANUSKA FORMATION
HARENDEEN LIMESTONE
NAKNEK FORMATION
CHINITNA FORMATION
TUXEDNI GROUP
TALKEETNA FORMATION
KAMISHAK FORMATION AND COTTONWOOD BAY GREENSTONE

Figure 6. Comparison of geologic stratigraphic columns of Cook Inlet and Queen Charlotte Basin (after Magoon and Claypool, 1981 and Magoon and Egbert, 1986)

2. CALIFORNIA

Biostratigraphic studies indicate correlations with basins in southern California and northern Mexico (Hamilton and Cameron, 1989).

Petroleum geology of Great Valley and southern California continental borderland basins may provide useful comparisons based on similar age and tectonic setting (Hamilton and Cameron, 1989). The Queen Charlotte Basin has been compared to the borderland based on similar Neogene tectonic history and structural characteristics (Rohr and Dietrich, 1992). Several Neogene strike-slip basins occur in the California borderland region including the oil rich Los Angeles Basin estimated at 10 Bbbl (Biddle, 1992). The primary difference between the basins is type of source rocks, thereby limiting comparison of petroleum yield estimates. However, strike-slip basins are considered to be above average in terms of hydrocarbon potential.

3. EAST COAST

Hannigan et al. (1998) note that no direct analogues can be drawn between the Queen Charlotte Basin and other Canadian oil provinces. In ranking median recoverable resource estimates, the Queen Charlotte Basin with 2.6 Bbbl of oil and 20 Tcf of gas has a gas endowment comparable to the Scotian Shelf (18 Tcf, Wade et al, 1989) and oil reserves of about half those in the Jeanne D'Arc Basin (4.7 Bbbl, Sinclair et al., 1992). The Jeanne D'Arc also contains an estimated 13 Tcf of gas along with 1 Bbbl of oil for the Scotian Shelf. All these basins are overshadowed by a potential 7 Bbbl of oil and 68 Tcf of gas proposed for Beaufort-MacKenzie Basin in the Canadian Arctic (Dixon et al, 1994).

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Appendix 8: Faulting and Seismicity in Queen Charlotte Basin[6]

Seismicity is a potential hazard in the Queen Charlotte Basin. Earthquakes from the nearby plate boundary, the Queen Charlotte Fault, can be as large as M=8.1 (Fig. 1) and magnitude 6 events are common on the Revere-Dellwood Fault to the south. These events can cause considerable shaking in the adjacent plate margin. Small earthquakes occur frequently in the Queen Charlotte Basin itself (Bird, 1997), but appear to be concentrated in northern Hecate Strait. This can be explained as a part of the transpressional deformation occurring across the plate boundary in the last 5 Ma (Rohr et al., 2000).

Assessments of seismicity include modern records of earthquake activity but also geophysical and geologic knowledge of structures and evidence of recent movement on faults. Electronic records of seismicity are most useful but, unfortunately, are restricted in time and place. The geologic record can show the longer term results of activity. Commonly sought evidence of recent activity is a fault cutting the ground or seafloor. However, many factors can work to overprint such a signature and inactive ancient faults exposed at ground level may have topographic offset simply because of erosion. Blind thrusts may not cut the surface yet shaking from earthquakes on them can be quite destructive (S.C.E.C., 1994).

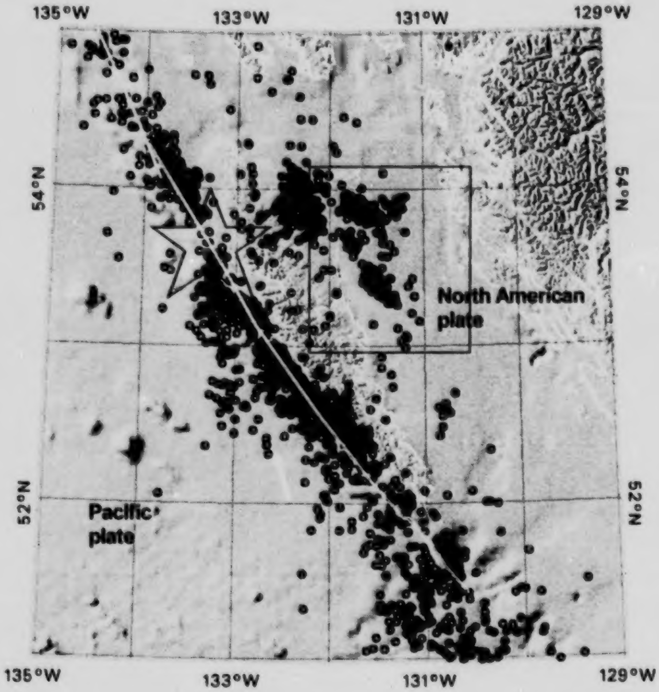

Figure 1. Microseismicity from Bird (1997) plotted on bathymetry; each event is shown as a single uniform-sized circle. Queen Charlotte Fault (white line) is the plate boundary between the Pacific and North American plates; the arrow indicates relative plate motion. Magnitude 8.1 event is shown as a star; magnitude 5.3 event is shown as a small white box. Large black box encloses area of Figure 2.

Side-scan, high resolution seismic reflection (Barrie et al, 1990) and multi-channel seismic reflection data (Rohr and Dietrich, 1992) have been examined (Appendix) in the regions of earthquake activity in the Queen Charlotte Basin determined by Bird (1997) (Fig. 2). Broad anticlines cut by vertical faults and networks of smaller branching faults are observed in northern Hecate Strait (Fig. 3). The structures are consistent with focal mechanisms dominated by strike-slip and thrust events (Bird, 1997) with the occasional extensional event, as in any transpressional environment. Structure in the Tertiary sediments within 100-200 m of the seafloor was not imaged by existing seismic reflection data; data to map this area should be collected.

Earthquake location programs used by Bird assumed that the upper crust has a uniform velocity of 5.8 km/s and ignored the presence of lower velocity sediments so one can not incontrovertibly place an earthquake on a known fault. The co-existence of seismicity and significant deformation of both sediments and basement in Hecate Strait is surely not fortuitous. These structures should be considered capable of motion.

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[6] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Kristin M. M. Rohr. December 2001.

Other faulted folds in the region have been mapped (Rohr and Dietrich, 1992), but are not currently associated with seismic activity. Detailed information for micro-earthquakes is best for the period of 1982 to 1996 when extra stations were placed in the region (Bird, 1997). Whether that 14-year time slice is representative of the last 100 years and can be reliably used to predict the next 10 to 50 years of seismicity is unknown. Rohr et al. (2000) make arguments based on the geologic, morphologic and paleomagnetic data of the Queen Charlotte Islands that deformation has proceeded from south to north in the last few Ma; one could reasonably expect seismic activity to remain concentrated in the north. This does not, however, preclude the possibility of earthquakes occurring elsewhere in the weak and regionally stressed crust underlying the Queen Charlotte Basin.

Tectonically and structurally the Queen Charlotte Basin is similar to the Miocene Basins in California which are rich sources of petroleum production. Producing wells occur both on land and offshore. Both regions experienced Miocene extension followed by Pliocene compression and are near transform plate boundaries. Other areas with both production and proximity to transform plate boundaries include Indonesia and New Zealand.

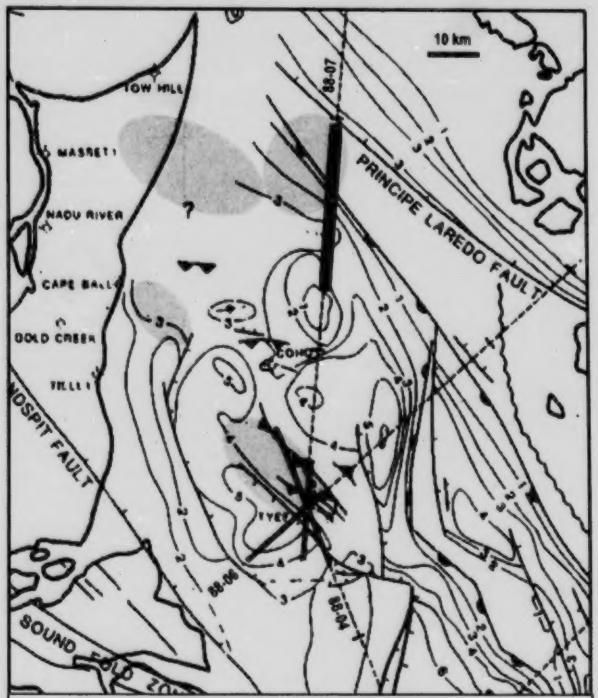

Figure 2. Sediment thickness map for northern Hecate Strait (after Rohr and Dietrich, 1992). Dashed lines are multi-channel seismic reflection profiles collected in 1988. Grey ellipses enclose clusters of microearthquakes identified by Bird (1997). The northern cluster (near the Principe Laredo Fault) includes the M=5.3 event in 1990 and its aftershocks. The portion of line 88-07overlying this cluster is shown in Figure 3.

Ground motion calculations by the Geological Survey of Canada in the Queen Charlotte Basin indicate that a large structure roughly ten-stories tall has a 10% chance of experiencing movement of 0.16 to over 0.32 m/s in a 50-year period from seismic waves with a frequency of 1 Hz. A smaller building has a 10% chance of experiencing an acceleration of 0.11 to over 0.32 g in a 50 year period from seismic waves with a frequency of 5 Hz. The greatest risk is from large events on the plate boundaries. Differences in structure between oil rigs and office buildings as well as local substrate should be taken into account when assessing hazards due to seismicity in Queen Charlotte Basin. Areas of southern California producing oil have a 10% chance of experiencing an acceleration of 0.1 to over 0.6 g in a 50 year period.

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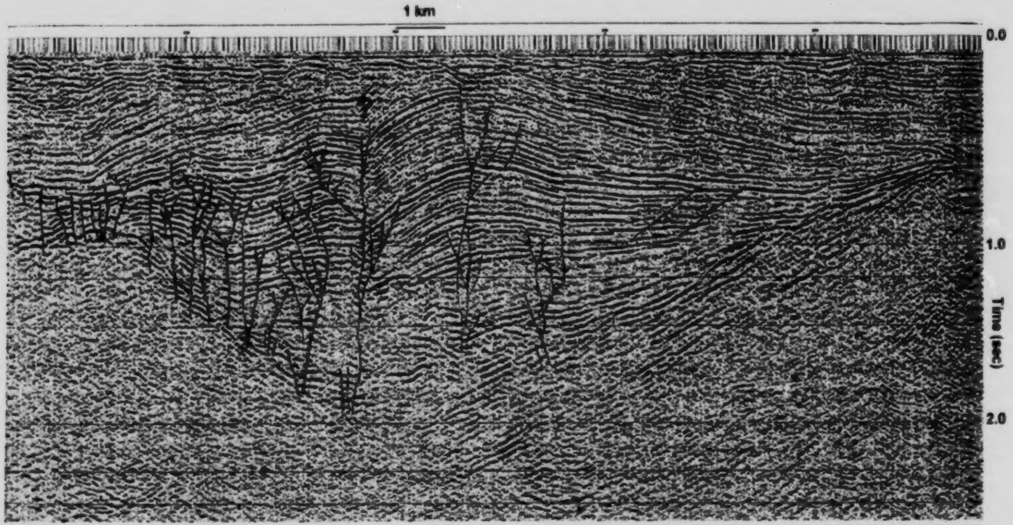


Figure 3. Migrated section of line 88-07. This sub-basin occurs south of a seismically active area in northern Hecate Strait.

Appendix 9: California – An Analogue to Queen Charlotte Basin?[7]

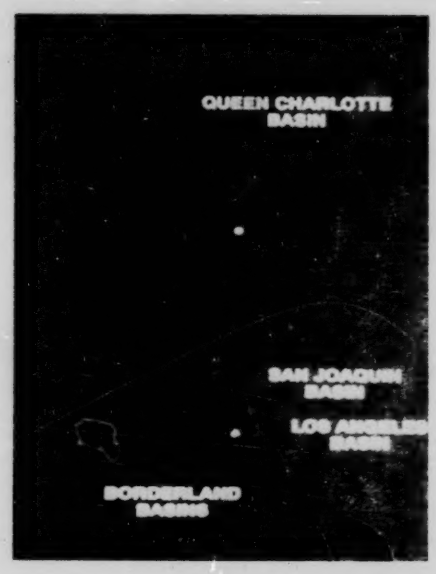


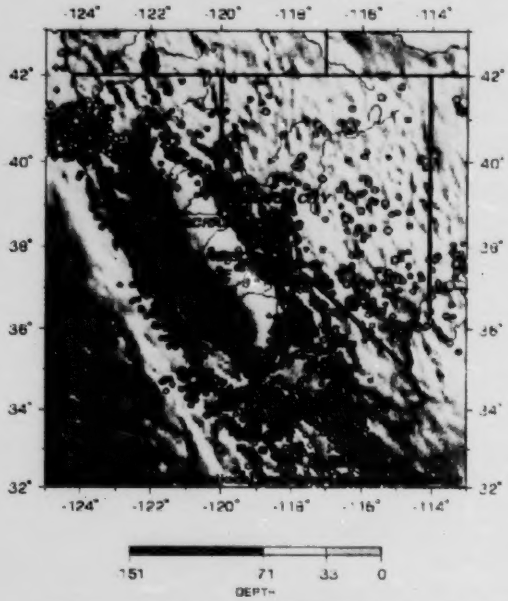
Figure 1. Cartoon of Pacific and North American plate boundaries.

Tectonically both the Queen Charlotte region and California are dominated by a transform plate boundary between the Pacific and North American plates (Fig. 1). In California the plates are moving at a relative rate of 40 km/Ma which is mainly carried by the San Andreas Fault, but also by a number of secondary faults (Fig. 2). Off British Columbia the rate is 48 km/Ma and is almost entirely carried by the Queen Charlotte Fault west of the Islands.

Geometry of the plate boundary in California has changed dramatically as two triple junctions migrated along the coast; the main transform fault has progressively moved inland over the years. The geometry of the Queen Charlotte Fault seems to have been fairly stable over tens of millions of years; triple junction complications have mostly been accommodated in oceanic crust to the south.

Both regions experienced extension in the Miocene followed by basin inversion and compression in the Pliocene. Small changes in the relative plate motion can explain the Pliocene compression but not the Miocene extension.

Hundreds of scientists have been detailing California's geology and tectonics since the 1800's. Many current studies are aimed at understanding seismicity including measuring the strain partitioning along the different faults in California in order to delineate potential hazards (Fig. 3). Over 700 hundred seismometers monitor every temblor; in some areas events can be mapped with accuracy of meters resulting in new insights into how faults behave. In contrast the Queen Charlotte region has only 9 permanent seismograph stations; the depth distribution of earthquakes on the Queen Charlotte Fault is entirely unknown. Stations lie east of the Fault and do not provide a good geometry to determine depth. Earthquakes on the shelf occur to depths of 15-20 km (Bird, 1997).


Seismicity of California

1977 - 1996

Figure 2. Seismicity is distributed along many faults in California.

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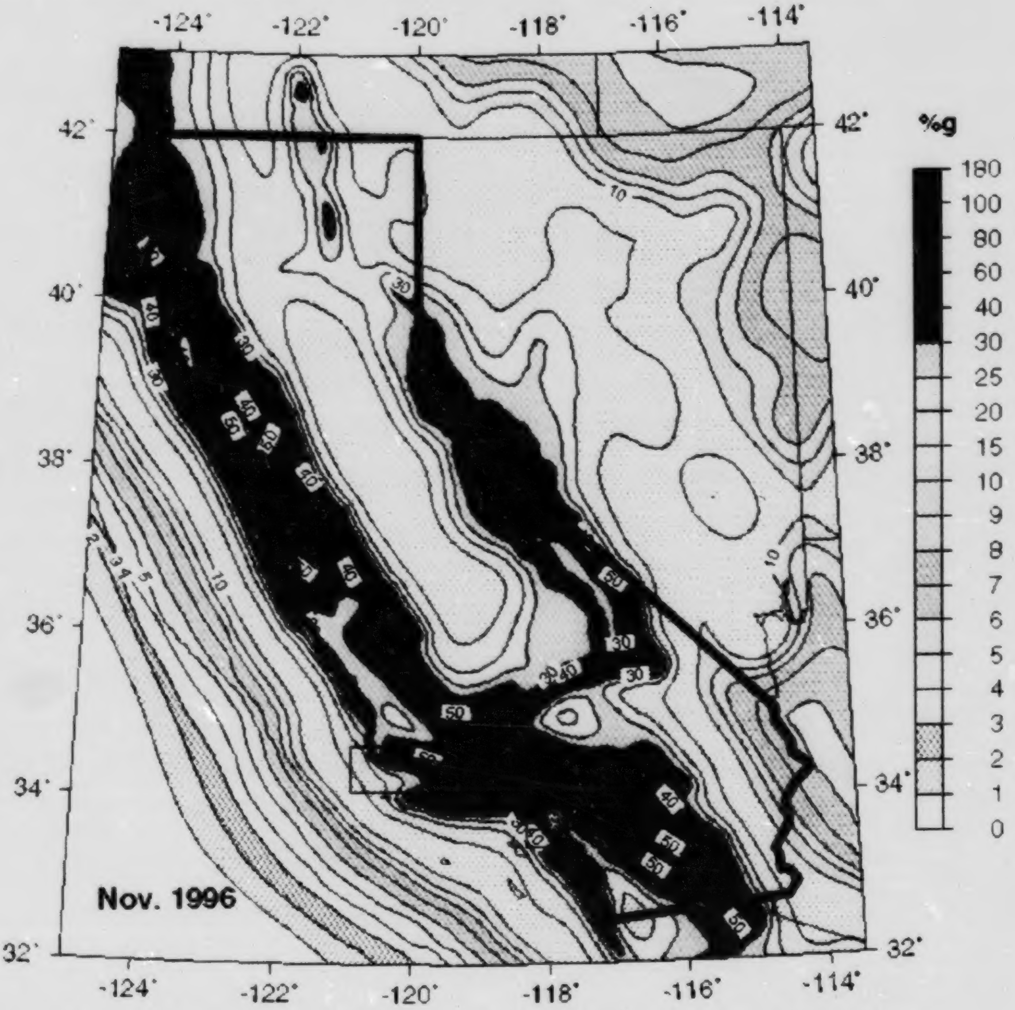
[7] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Kristin M. M. Rohr. December 2001.

Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary


-124°
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Nov. 1996

For California portion: U.S. Geological Survey - California Divison of Mines and Geology
For Nevada and surrounding states: USGS

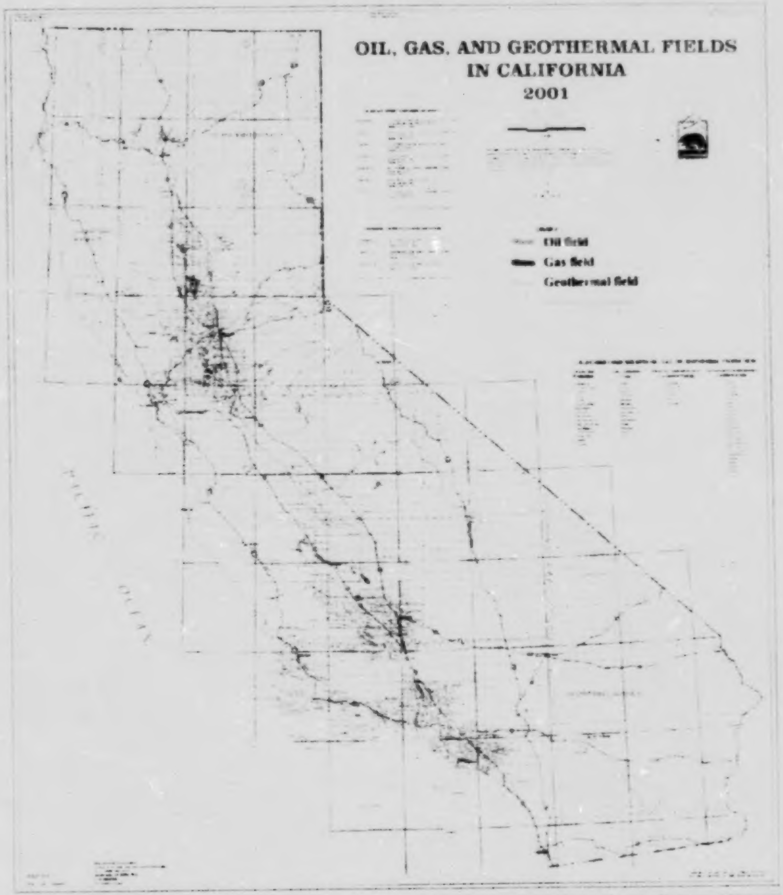

Figure 4. Oil, gas and geothermal fields in California, 2001, from California Division of Oil, Gas, and Geothermal Resources.

Seismicity and Oil and Gas Production in CA

California has a long and rich history of utilizing and producing oil and gas. In the 1500's natives were using asphaltum from ground seeps to seal containers; Europeans learned to caulk boats with it. The first commercial well began production in 1876; production has varied since then, but reached a peak in 1985 at 423.9 barrels of oil. Oil wells tend to be in southern California and purely gas wells in northern California (Fig. 4). In 2000 46,799 oil wells and 1,169 gas wells were producing hydrocarbons from 288 fields (Fig. 4); total production was 307.4 million barrels of oil and 379.1 billion cubic feet of gas. 1,412 offshore wells accounted for 17.6% of the total oil production and are largely found off southern California in a seismically active region. Areas within 3 miles offshore are regulated by the state and the rest by the federal government.

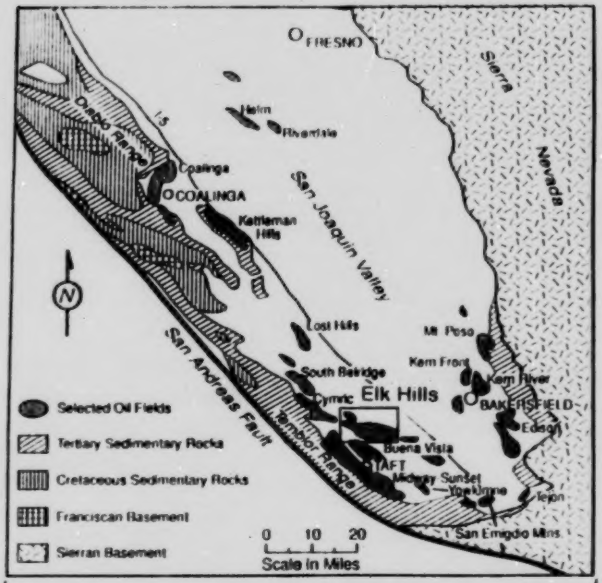
FRESNO
Sierra
Nevada
15
Diablo Range
Helm
Riverdale
Coalinga
COALINGA
San Joaquin Valley
Kettleman Hills
N
Lost Hills
Mt Poso
South Belridge
Kern Front
Kern River
Cymric
Elk Hills
BAKERSFIELD
Edison
San Andreas Fault
Temblor Range
Buena Vista
TAFT
Midway Sunset
Yowlumne
Tejon
San Emigdio Mtns
● Selected Oil Fields
▨ Tertiary Sedimentary Rocks
▥ Cretaceous Sedimentary Rocks
▦ Franciscan Basement
Sierran Basement
0 10 20
Scale in Miles

Figure 5. Cartoon of San Joaquin sedimentary basin highlighting selected oil fields (from Reid and Wilson, 1990). Note that many are within 20 miles of the San Andreas Fault. 38,733 wells within this entire region produced 217.3 million barrels of oil or 71% of California's oil in 2000.

Damaging earthquakes have also been a part of California's history killing hundreds of people and causing hundreds of millions of dollars of damage over time. In available accounts of damage caused by major earthquakes, damage to wells and ensuing oil spills is not mentioned (e.g. Dept. of Conservation; von Hake, 1971). An official from California's Division of Oil, Gas and Geothermal Resources which regulates drilling and production of wells could recall no instance of damage done to offshore production facilities by an earthquake. An earthquake near Coalinga (Fig. 5) (M=6.7, 1983) on a blind thrust caused minor damage to storage tanks which were stressed by sloshing fluids. In any event these tanks are surrounded by berms to protect against the more imminent danger of leakage from corrosion. However, nearby houses and commercial buildings of unreinforced adobe and concrete were heavily damaged leaving 1,000 people homeless.

Spills from blow-outs were not unusual in early days of drilling, but engineers learned to control the spontaneous flow of oil out of most pressured zones. The last major blow-out offshore occurred in 1969 off Santa Barbara in federally regulated land. The state placed a temporary moratorium on drilling offshore until stricter regulations were in place to prevent another such occurrence. The blow-out was not caused by an earthquake but rather the simple effect of drilling into a highly pressured zone. Since that time exploration and production have been highly regulated but active at a modest level. Eleven development wells were drilled in Federal lands in 2000. In 1995 ARCO and a subsidiary spent US$ 2.8 million on a 3D survey covering a 10 square mile area off Long Beach to develop a drilling program.

Seismic activity creates some risk but geologically has created structures favorable to trapping hydrocarbons. Slight compression across the plate boundary has folded and faulted the adjacent basins into structures which trap hydrocarbons; the same kind of structures are observed in Hecate Strait.

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Appendix 10: Non-Potential of Natural Gas Hydrate Occurrence in Queen Charlotte Basin[8]

Natural gases such as methane, ethane, propane typically occur as a gas phase on the Earth (Figure 1, Kvenvolden and Lorenson, 2001). However under quite special conditions these gases can combine with water to form a solid form called "Gas Hydrate", or "clathrate". Globally these gas hydrates represent a tremendous reserve of natural gas, especially methane, in the Earth. The global amount of natural gas tied up in hydrates is estimated to be 10,000 Gt or 2×10^{16} m^3 (= 6×10^5 tcf), e.g., Kvenvolden (1993). For comparison Figure 2 shows the amounts of natural gas contained in conventional reservoirs is about one-half of this amount. The west coast of North America, including the west coast of Vancouver Island is well known to have large accumulations of gas hydrate in the specific shallower (ca. 0 – 250 m) offshore sediments. Because of the potential economic significance of these hydrates, there is considerable interest in their formation and occurrence.

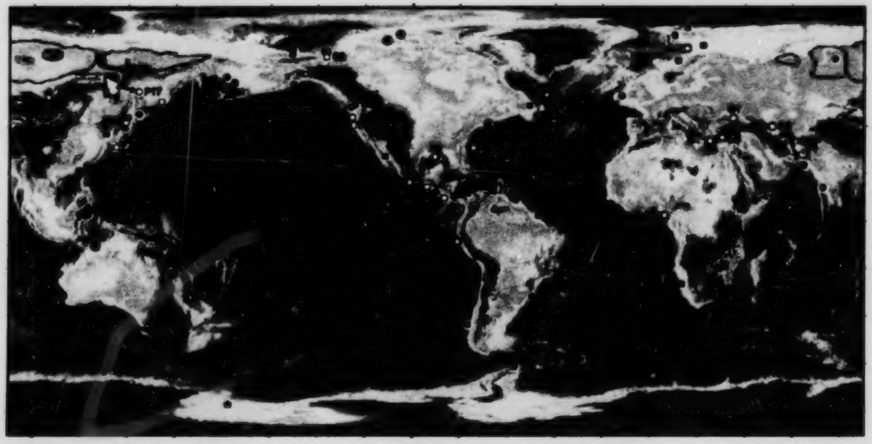

Figure 1. Global distribution of natural gas hydrates (after Kvenvolden and Lorenson, 2001).

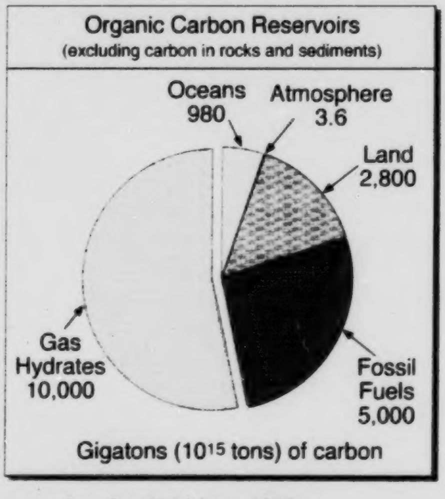

Figure 2. Major organic carbon pools (after Whiticar, 1990)

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[8] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

In addition to their economic potential, gas hydrates are of interest because they:

1. Pose geotechnical concerns, such as large-scale submarine slumping ,
2. Can cause difficulties during drilling operation due the possibility of overpressured gases beneath the gas hydrate stability zone,
3. Are a major factor in greenhouse gas storage and climate change.

There are three primary conditions that must be satisfied in order that methane hydrates are naturally able to form and be preserved. These are:

1. Sediment porewaters (or rarely water column) is saturated with CH_4 (free gas)
2. Sufficient pressure is available (hydrostatic pressure, P)
3. The temperature (T) of the water and sediment is suitably cold.

The first condition, i.e., that the waters are saturated with respect to methane is frequently met in shallow coastal waters, such as found in the Queen Charlotte Basin. There are numerous sources for this methane, but most commonly in this setting the gas is of bacterial or thermogenic origin, e.g., Whiticar (1990).

The combination of temperature and pressure (water depth) necessary for methane hydrate formation and stability are shown in Figure 3. In the lightly shaded region, the pressure is either too low (too shallow) or the temperature too high for hydrate to exist (e.g., Sloan, 1998). The darker region in Figure 3 shows the depth-temperature (P, T) region in which gas hydrate is stable. For illustration, the range in temperature and water depths in the Hecate Strait are given as the white box in the figure. The specific situation in the Hecate Strait is more clearly indicated in Figure 5. This figure incorporates the usual maximum and minimum temperatures measured at different water depths in the summer and winter (Crawford, 2001). The maximum temperature of ca. 16°C is recorded in the summer surface waters (Figure 4, after J. Gower and J. Wallace, Institute of Ocean Sciences, DFO, Sidney). The coldest water is 5 – 6°C in the deeper waters, e.g., 200 m.

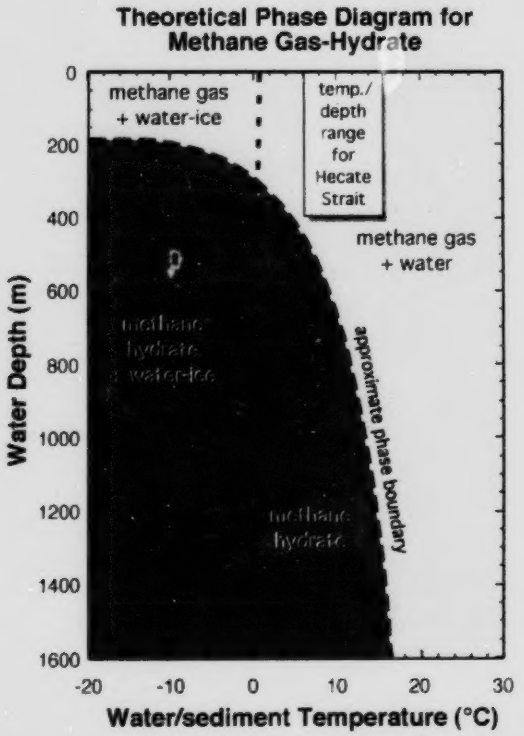

Figure 3. Phase Stability of methane and methane hydrate (after Sloan, 1998)

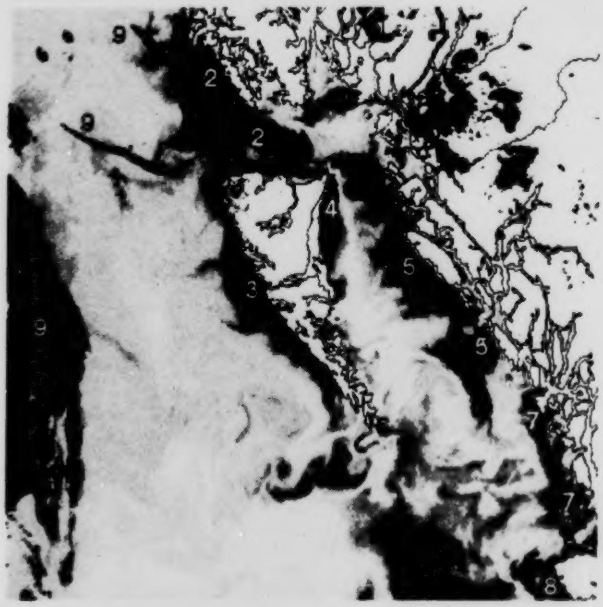

Figure 4. Summer surface water temperature (after Gower and Wallace, 2001) Cool water (10°C appears blue, warmer waters are in red, ca. 16 °C).

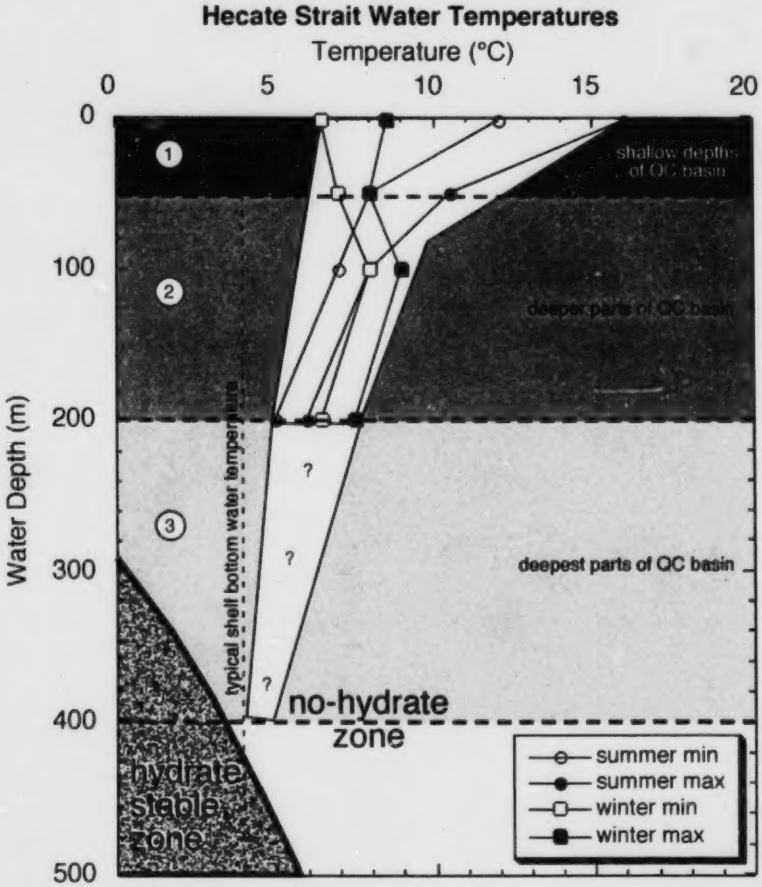

Figure 5. Hydrate non-occurrence in the Hecate Strait

Figure 5 shows this temperature distribution with depth together with the known P,T methane hydrate stability zone. This figure clearly illustrates that even if the waters were saturated with methane the typical waters of the Hecate Strait are not within the hydrate zone. The form of any methane in these waters would be either dissolved or free gas. The situation does not change in the sediments, i.e., any hydrocarbons gases would be in gas form and not hydrate. This is because the temperature will continue to increase with sediment depth due to the geothermal gradient.

It should be noted that offshore, where the water depths (pressures) are greater and the bottom waters are colder (2 – 4 °C), hydrates are stable and can accumulate. However, these hydrates only form if sufficient gas is present. Such is the case in the areas such as the Cascadia Margin, e.g. off Vancouver Island and Oregon coast.

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Appendix 11: Overview of Geologic Hazards to Offshore Petroleum Development – British Columbia Continental Shelf[9]

Introduction

Geologic hazards are those conditions or active processes which pose a potential threat to petroleum exploration or development activities, or to the longer term security of seafloor production installations (e.g., wellheads, pipelines). In many instances these hazards are interrelated (e.g., earthquakes and slope stability) and in others can be related to oceanographic conditions (waves and currents, and sediment mobility). Extreme oceanographic conditions themselves will not be considered in this brief overview whereas sediment mobility as a resultant hazard will be addressed. Clearly other hazards also exist, including oceanographic, meteorological and anthropogenic; these are not considered here.

The following summary will examine the important geologic hazards which exist in various areas on the exposed continental shelf off British Columbia. These include: bedrock outcrops; Holocene faults and associated seismicity; boulder beds; sediment mobility (large bedforms in high wave and current regions); mass wasting (underwater landslides); steep slopes; shallow gas; and, dynamic coastal processes. The scenario envisaged is one of offshore development and production with associated pipelines which traverse the shelf to an unspecified coastal site.

Clearly the regional understanding of seabed geological hazards is only as good as the overall knowledge of the surficial geology in the area. This has been assessed in an accompanying report. As well, many of the specific requisite studies to assess the extent and nature of certain hazards have not been carried out even in areas for which moderate to good knowledge of the surficial geology exists.

Nature of Geologic Hazards

Bedrock Outcrop

Extensive areas of outcropping bedrock at the seafloor could be problematic for drilling and may inhibit burial of pipelines. While burial of pipelines may not necessarily be a requirement everywhere, there would probably be zones where it is highly desirable (e.g., areas which may remain open to fishing; coastal approaches, etc.). Even if burial is not undertaken, outcropping bedrock can present concerns particularly in high current areas; lateral stresses on pipelines from strong seabed currents or "strumming" of the pipeline in areas of spans can result. Spans, if too great, can cause significant stresses in pipelines, shorten the design life of the structure and possibly lead to mechanical failure.

Holocene Faults and Associated Seismicity

Ground accelerations resulting directly from earthquakes can have both direct and indirect effects on all phases of offshore petroleum activity from exploration through to production. Lateral and vertical displacement (and possible rupture or collapse) of rigs and pipelines would be extreme direct effects of fault offset or extreme ground motions. Indirect effects, discussed in greater detail below, include sediment liquefaction and collapse, and a variety of mass wasting processes. All of these could impact wells or seafloor structures, including pipelines.

All of the areas under consideration that lie north of Barkley Sound on southern Vancouver Island are within Canada's highest earthquake hazard category. These areas can expect a greater than 10 percent chance of having ground accelerations exceeding 0.32 g and horizontal velocities exceeding 0.32 ms^{-1} within a 50 year period.

Boulder Beds

Surficial boulder and cobble concentrations exist in many areas of the British Columbia continental shelf and within some of the unconsolidated glacial sedimentary units. They pose concerns for drilling operations and pipeline burial and, in the absence of burial, can result in a highly irregular surface which can lead to significant pipeline spans.

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[9] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Brian Bornhold and John Harper, December 2001.

Sediment Mobility

Seafloor sediments are subject to transport by surface waves and tidal currents over much of the continental shelf of British Columbia. As a result of the exposed conditions and high wave regime in much of the area, large (about 0.5 – 1.0 m) sedimentary bedforms (oscillation ripples and megaripples) in coarse sands can be produced by surface waves in water depths in excess of 100 m. Similarly, topographically constrained tidal currents in some localities can result in migrating sandy bedforms (sand waves) which are more than 5 m in amplitude. Larger accumulations of mobile sands and gravels, sand ridges, can be up to 10 m high, one hundred metres wide and several hundred metres long.

A highly mobile seabed can have several impacts including burial, scour and lateral dislocation of surface-laid structures (e.g., pipelines), spans which result from removal of sediment beneath pipelines, and abrasion of rigs , wellheads and pipelines by the moving sediment.

Mass Wasting

A variety of slope failure processes in zones of high relief can pose significant hazards to rigs, wellheads and pipelines. These include liquefaction failure and collapse, direct lateral impact from moving sediment masses on rigs, anchors and pipelines, and scour by flow slides and turbidity currents. Causes of mass wasting can include earthquakes, storms and rapid sediment deposition on steep slopes.

Steep Slopes

Steep slopes of diverse origin can be of concern for pipeline routes and production facilities. Construction on steep slopes may, in some instances, require added measures to ensure that pipelines are stabilized. Slopes pose a particular hazard when coupled with other conditions or geological processes (e.g., shallow gas, earthquakes or slope instability). Scarps and slopes may be wave-cut in shallow water (or as relict deeper water features), the result of current erosion, past glacial erosion, tectonic processes (faulting) or mass wasting.

Shallow Gas

Accumulations of biogenic gas (primarily methane) are common in areas of present day mud accumulation on the shelf and especially in coastal fjords. Gas seeps into the water column from a deeper petrogenic source are much less common but do occur on the British Columbia continental shelf especially in Hecate Strait. Gassy sediments have lower strength than gas-free sediments. As a result, structures emplaced on gas-rich sediments are at risk from liquefaction collapse and possible downslope failure. Sediment strength can be completely lost, for example, during earthquakes when trapped interstitial gas is suddenly released to the water column.

In some areas gas escape structures (pockmarks) on the seafloor have been mapped. Gas escape during some drilling operations can pose a hazard.

Dynamic Coastal Processes

Coastal processes, such as high rates of erosion and longshore drift, are of particular concern for landfalls of pipelines. These facilities must be designed so as to be protected from exposure, dislocation and possible rupture throughout the entire design life of the facility. In some areas, rates of coastal erosion are in excess of several metres per year and would necessitate adequate burial and setbacks of coastal terminations to account for changes which would be anticipated over the course of several decades.

Regional Summary

Vancouver Island Shelf

Bedrock Outcrop. Bedrock outcrop dominates in the very nearshore area of most of the west coast of Vancouver Island. Elsewhere, extensive exposed bedrock outcrop occurs on the inner shelf north of Nootka Sound and especially in a broad area around the Scott Islands. These areas include zones of exposed low-relief sedimentary rocks (mostly mudstones) south of Brooks Peninsula and around the Scott Islands; a band of discontinuous, high-relief, rugged volcanic rocks extends from Brooks Peninsula towards Cape Scott. Elsewhere on the shelf Holocene sediments are very thin and often absent; locally exposed low-relief Tertiary bedrock and Quaternary sedimentary units occur at the seabed in these areas.

Holocene Faults and Associated Seismicity. The Vancouver Island continental margin is a subduction zone, where the Explorer and Juan de Fuca plates are descending beneath the western edge of the North America Plate. Thus, the area is seismically very active with the potential for catastrophic giant or megathrust earthquakes (>M8.0). Numerous faults of different types exist throughout the area: several shallow faults are known to displace Pliocene and Quaternary sediments on the shelf and are associated with topographically significant structures (anticlines) on the mid-shelf off Nootka Sound; the Nootka Fault is a coast-normal transform fault which extends into Vancouver Island (separating the Explorer from the Juan de Fuca Plate) with significant associated seismicity; crustal earthquakes with historical magnitudes as high as M7.0 (1918) and M7.3 (1946) are frequent on Vancouver Island.

Boulder Beds. Since the Vancouver Island shelf was minimally galciated north of the latitude of Tofino, boulder beds are concentrated on the mid-shelf only on banks around the troughs off Barkley Sound. Boulders up to several metres in diameter have been identified in these morainal deposits. Elsewhere, boulder and cobble concentrations are restricted to inner shelf and coastal areas

Sediment Mobility. Wave-generated ripples and megaripples (about 0.5 m amplitude) are known from the shelf north of Brooks Peninsula in water depths of more than 100 m water depth and on the mide-shelf off Barkley Sound. It is expected that similar features will exist on other parts of the Vancouver Island shelf as well. Current-generated sedimentary structures, including relatively thin rippled sand ribbons occur near the Scott Islands where tidal currents pass between the islands. Some sediment transport by tidal currents has also been documented in the vicinity of high-relief bedrock on the inner shelf north of Brooks Peninsula and along the perimeter of the glacially carved troughs off Barkely Sound where fine sediments are accumulating.

Mass Wasting. Mass wasting is known from only two settings on the Vancouver Island shelf: the shelf edge and within the troughs on the inner and mid-shelf off Barkley Sound. Canyons indent the edge of the continental shelf at water depths of 200-250 m; the heads of these canyons are sites of steep scarps and significant mass wasting. The glacially carved troughs off barkley Sound are characterized by steep slopes and localized failures.

Steep Slopes. High relief is present on the outermost shelf, especially in the vicinity of canyon heads, along the outer margins of the Barkley Sound troughs and on the rugged bedrock areas north of Brooks Peninsula.

Shallow Gas. Shallow gas is not common on the Vancouver Island shelf except in the fine sediments accumulating in the Barkley Sound troughs. Elsewhere the Holocene sedimentary cover is very thin (< 0.5 m in general). Gas is common in the muddy sediments accumulating in the many fjords along the coast and gas hydrates are known to occur on the continental slope of Vancouver Island.

Dynamic Coastal Processes. Sedimented coasts are most prevalent south of Hesquiat Peninsula to Barkley Sound and in the vicinity of Cape Scott. Low-gradient extensive beaches with fine to medium sands prevail in the Long Beach area near Tofino. Elsewhere the coastline is predominated by bedrock with small embayed beaches of generally coarser sediments.

Queen Charlotte Sound

Bedrock Outcrop. Exposed bedrock mainly occurs in the vicinity of the Scott Islands, and in a broad zone of rugged relief in easternmost Queen Charlotte Sound adjacent to the British Columbia mainland. Minor local occurrences have been documented from the southern banks in the central part of the sound.

Holocene faults and Associated Seismicity. The region lies opposite the ridge-trench-transform triple junction located along the continental margin. Thrust faulting dominates to the south and along Vancouver Island while dextral strike slip motion occurs to the north along the Queen Charlotte Transform Fault. While Queen Charlotte Sound lies adjacent to one of the most seismically active areas in Canada, few earthquakes of M5 or greater have actually been recorded in the sound. Faulting in Tertiary strata in Queen Charlotte Sound is well documented but no faults are known to offset Quaternary strata or break through to the seafloor. That being said, faulting related to Quaternary post-glacial loading and isostatic rebound has been documented along some of the prominent glacial troughs which travese the shelf. These troughs do not appear to owe their origin to underlying Tertiary faults.

Boulder Beds. The only known areas of boulder fields are in the northeasternmost part of Queen Charlotte Sound along the eastern edge of Moresby Trough. Gravelly and cobbly sediments occur frequently on the three banks in the central part of the sound.

Sediment Mobility. The highly exposed banks of Queen Charlotte Sound exhibit abundant evidence of sediment mobility in the form of megaripples, linguoid ripples, sand ribbons and sand waves. These features are most prevalent on and around the major banks in the central part of the sound to water depths of about 200 m. Oscillation ripples have been documented on the outer shelf of the southern banks to water depths of 90 m. Erosion of sediments by topographically enhanced tidal currents is known from several of the troughs which cross the sound.

Mass Wasting. Mass wasting is known only from the steep margins of Moresby Trough along northern Queen Charlotte Sound and in the complex region of canyon heads which incise the central shelf edge.

Steep Slopes. The area was traversed by glacial tongues emanating from the British Columbia mainland fjords through Hecate Strait. These glaciers incised prominent troughs through the shelf area resulting in locally very steep slopes. Of greatest importance in this regard is Moresby Trough along the northern edge of the sound where slopes in excess of 15° are common. Other steep slopes occur on the outer continental shelf where canyons indent the continental margin.

Shallow Gas. Shallow biogenic gas accumulations are only known from the deeper parts of Moresby Trough (about 300-400 m water depth). Pock marks or gas escape structures occur in about 150-250 m water depths in the eastern part of the sound; gas in the underlying sediments was not detected acoustically in these areas.

Dynamic Coastal Processes. There are no significant areas of sedimented shorelines where extensive erosion, sediment transport or deposition are occurring. Most of the coastlines surrounding the sound are rugged bedrock with only localized embayed beaches.

Hecate Strait

Bedrock Outcrop.Outcrop at the seafloor is restricted primarily to the eastern margins of the strait, in a broad zone of complex and rugged topography along the mainland coast, and along the eastern side of Moresby Island. Outcropping bedrock is not known from the central parts of the strait except in the walls of southernmost Moresby Trough.

Holocene Faults and Associated Seismicity. The region lies adjacent to the Queen Charlotte Transform Fault along which the largest recorded earthquake (M8.1) occurred

in 1949. While the region was sparsely populated at the time, this earthquake caused considerable damage in the Queen Charlotte Islands and in Prince Rupert. While there are many known Tertiary faults in Hecate Strait, little recorded seismicity appears to be associated with them and there are no documented instances of seafloor displacement. Any Quaternary faulting in the area appears to be related to isostatic rebound and post-glacial loading

Boulder Beds. Boulder fields are known to occur on some of the shallow banks (e.g., Laskeek Bank) and along the slopes of Moresby Trough. Dogfish Bank off Graham Island is poorly studied but is anticipated to have many areas of boulder concentrations.

Sediment Mobility. Sand waves are common along the margins of Dogfish and Laskeek Banks, particularly on the steep bounding slopes leading to Moresby Trough. As well, linguoid bedforms and sand waves are found in the narrow channels between southwestern Laskeek Bank and Moresby Island in southern Hecate Strait; amplitudes of these features can exceed 3 m.

Megaripples, sand waves and sand ridges are particularly important in the vicinity of Rose Spit and Rose Bar at the northeast corner of Dogfish Bank. These features are the result of storm-driven sand motion on the shelf under the influence of topographic steering of tidal and wind-driven currents. In this area amplitudes of the sand waves and sand ridges can exceed 6 m.

Mass Wasting. Slope failures have been identified from several localities in Hecate Strait, particularly along the steep slopes of Moresby Trough and in the deeply incised channels between Laskeek Bank and Moresby Island.

Steep Slopes. Wave cut terraces, produced during periods of lower sea level stand in the early Holocene mark the western edge of Moresby Trough through out Hecate Strait. As many as three separate "steps" in the seafloor topography occur and can be traced over many tens of kilometres; each "step" is from 10 to 30 m and can exhibit slopes greater than 15°. Steep slopes also exist along the margins of some of the deeply incised troughs between Moresby Island and Laskeek Bank in southern Hecate Strait.

Shallow Gas. Shallow gas concentrations are common throughout the deeper parts (> 100 m) of Moresby Trough where thick sequences of muddy Holocene sediments have accumulated. As well, local occurrences of gas exist along the easternmost edge of Dogfish Bank; it is conceivable that these may have a deeper petrogenic origin.

Dynamic Coastal Processes. The eastern coastline of Graham Island is largely dominated by a thick sequence of unconsolidated glacial outwash deposits capped locally by Holocene dunes. These sediments are retreating rapidly, with the eroded sediments being swept northwards towards Rose Spit. While average erosion rates apear to be about 1 m per year, retreat is highly episodic; in 192-1993, for example, 11 m of land was lost at Cape Fife and 1.5 m was lost in a 24-hour period at the same site in 1994. Numerous, ephemeral shore-attached bars are associated with the high rates of longshore drift along eastern Graham Island.

Dixon Entrance

Bedrock Outcrop. Rugged outcrops of bedrock occur at both the eastern and western extremities of Dixon Entrance on Celestial Reef and Learmonth Bank. Along the nothernmost edge of the strait, adjacent to Alaska, bedrock reefs extend offshore. Nearshore areas are characterized by outcropping bedrock in the easternmost parts of the strait and along Graham Island, particularly west of Masset Inlet. Low relief sedimentary bedrock of Tertiary age outcrops locally on the eroded seabed in McIntyre Bay.

Holocene Faults and Associated Seismicity. Many faults have been identified in the sedimentary bedrock which underlies Dixon Entrance and at two localities, immediately east of Learmonth Bank and adjacent to a zone of exposed bedrock in central Dixon Entrance, normal faults which cut the present seafloor have been inferred. There is no documented association between these faults and historical seismicity in the area. Dixon Entrance lies immediately adjacent to and east of the Queen Charlotte Transform fault which is seismically very active; Canada's largest recorded earthquake (M8.1) occurred along northwestern Graham Island just south of the entrance to the strait.

Boulder Beds. Concentrations of boulders are common in Dixon Entrance from nearshore areas, especially off Graham Island west of Masset, on prominent banks and over large areas in the central strait to water depths of 250-350 m.

Sediment Mobility. Sedimentary bedforms indicative of active seafloor processes occur in several localities within Dixon Entrance. Of note are the large features located on the shelf north of Graham Island west of Masset. Megaripples, oscillation bedforms and sand waves occur in this area to water depths of up to 100 m. Similar features up to 2 m high have also been documented about 20 km north of Rose Spit in 150-200 m water depth on the flanks of a small topographic high. Relict deep water (>400 m) features also occur in Dixon Entrance and are believed to have been created during times of lowered sea level.

Mass Wasting. No specific examples of mass wasting have been identified in Dixon Entrance. This most probably is simply a reflection of the nature of surficial geology investigations in the deeper parts of the strait which have been restricted to coring and widely spaced seismic profiles. It is expected that failures will be concentrated near steep scarps at the edge of the shallow shelf off Graham Island and around the bank areas in the eastern and western strait (e.g., Learmonth Bank).

Steep Slopes. A wave-cut terrace and scarp lies off Graham Island just north of Masset in approximately 55 m water depth. Locally this scarp is more than 20 m high. Elsewhere steep slopes are mostly associated with bedrock-cored banks and shoal areas along the northern side of the strait, and at its eastern and western extremities.

Shallow Gas. The most significant area of biogenic gas accumulation in Dixon Entrance lies south and southeast of Celestial Reef (west of Dundas Island) in a thick sequence of Holocene muds. These sediments lie in 100-200 m water depth.

Dynamic Coastal Processes. The coastline of McIntyre Bay off northeast Graham Island is the result of beach ridge accretion over the past several thousand years. Sediments are swept southeastwards from the bay into the coastal zone. There is still debate as to whether sand from south of Rose Spit brought northward by longshore drift is a source of additional sand for these beach ridges. The significant longshore drift in McIntyre Bay is towards the northeast (Rose Spit). Elsewhere in Dixon Entrance the coastline is mostly bedrock-dominated with short embayed beaches of coarse sediments.

Regional Sensitivity to Oil Spills

Although the potential for a catastrophic oil spill from an uncontrolled blow-out is remote, the possibility does exist and is of significant concern in the planning process. A spill in the region would almost certainly impact shorelines, could impact sensitive biological resources and will alter human-use activities, such as tourism, commercial and recreational fishing. The province (Ministry of Sustainable Resource Management) is presently near completion on a province-wide coastal inventory that incorporates a state of the art. oil spill sensitivity analysis (see Howes *et al* 1993; 1999); however, the North Coast region is one that remains incomplete at present (the sensitivity model may be complete in 2-3 years, depending on level of support from the provincial and federal governments). This sensitivity model incorporates sensitivities of resources to both spills and to spill cleanup efforts.

In modeling studies of possible blow-out scenarios, Chevron (1984) showed a general *zone of influence* from a catastrophic blow-out (Fig. 1). This *zone of influence* shows that oil could reach almost all shorelines around Queen Charlotte Sound, Hecate Strait and Dixon Entrance, including southeastern Alaska, Queen Charlotte Strait and Quatsino Sound. There are more than 18,000 km of shoreline within this *zone of influence*, although it is important to note that in event of an actual spill, the length of shoreline that could be oiled would be significantly less – the length of shoreline oiled in the *Exxon Valdez* spill was around 2,000 km, most of which was very light oiling (Table 1). The concept of a *zone of influence* is useful for delineating the total area that should be considered as part of the planning and evaluation process.

Table 1 1989 Shoreline Oiled (km) in the Exxon Valdez Spill (from Exxon 1991)

Category	Prince William Sound	Kenai-Kodiak	Total
heavy oiling	144	24	168
moderate oiling	96	24	120
very light to light oiling	531	1,255	1,786
		Totals:	2,074

Physical Sensitivity

Because the formalized oil spill sensitivity model has not been completed for the Mid- and North Coast Region, only a first approximation of sensitivity is possible. Two of the primary assumptions of the provincial spill model are (Howes *et al* 1993; p. 14):

> "*the oil residence determines the probable exposure of resources to oil*",
>
> "*oil residence on the shoreline is based on the physical properties of the shore*".

A generalized knowledge of the physical properties of the shore can be used as a first step in constructing a generalized sensitivity assessment (inset).

The generalized wave exposure categories for the North Coast region are illustrated in Figure 2 (after Howes *et al* 1997). The low wave exposure portion of this coastline comprises about 14,000 km, a substantial portion of the total coastline (~ 75%; including portions of southeast Alaska). This low energy shoreline is coast where one would expect substantial oil residence periods (months to years) if oil were stranded along the shoreline.

Detailed shoreline mapping of one portion of the North Coast has been completed with the Gwaii Haanas National Park Reserve (approximately 1,600km of shoreline; Harper *et al* 1994). The detailed mapping shows that about 55% of the shoreline is bedrock and 45% either sediment or a mixture of rock and sediment (gravel or sand & gravel); these types of sediment shoreline are moderately to highly permeable and would have generally moderate to high oil retention in the event of a spill. The substrate results are probably representative of other areas of the North Coast and suggest that about 50% of the coast has sediment or mixed rock and sediment shoreline of moderate to high permeability sediments.

Although this assessment is very general, it is clear that: (a) there are substantial portions of low wave exposure coastline on the North Coast; and, (b) a substantial portion of this low wave exposure shoreline has moderately to highly permeable sediments. The assessment suggests that a substantial portion of shoreline, about 6,000 km or 35% of the total, will have the highest oil residence class, with month to years of possible oil residence. There would be another 6,000 km of low energy, bedrock shoreline that will have moderate oil residence periods.

Physical Shoreline Properties

Influencing Potential Oil Residence

Wave Exposure – wave exposure is probably the most important factor supplying energy to the shoreline and is critical to the mechanical dispersal of stranded oil. High wave energy levels generally result in rapid mechanical removal of the oil from the shoreline; that is, a rapid natural recovery process. Shorelines with low wave energy levels typically show lengthy oil persistence due to the slow mechanical dispersal of stranded oil. This assumption is incorporated into the BC provincial sensitivity analysis (Harper *et al* 1991) and is incorporated into more generalized sensitivity analyses used worldwide (see Halls *et al* 1997). The assumption for this first approximation is that high wave exposure shorelines will have short oil residence periods (days to weeks) and that low wave energy shorelines will have lengthy oil residence periods (months to years).

Sediment Permeability – shoreline sediment permeability influences the depth of penetration and the volume of oil that is retained along different shoreline segments. Impermeable substrates such as bedrock or mudflats have low penetration, low overall retention and as a result, relatively short oil residence periods. Highly permeable substrates such as boulder and cobble beaches permit considerable penetration of stranded oil (>1 m) and large volume retention, estimated to be as high as one barrel of oil per linear metre of beach on some sections of the Prince William Sound shoreline that were impacted by the *Exxon Valdez* spill. As such, low permeability shore types are assumed to have shorter oil residence periods than high permeability shore types.

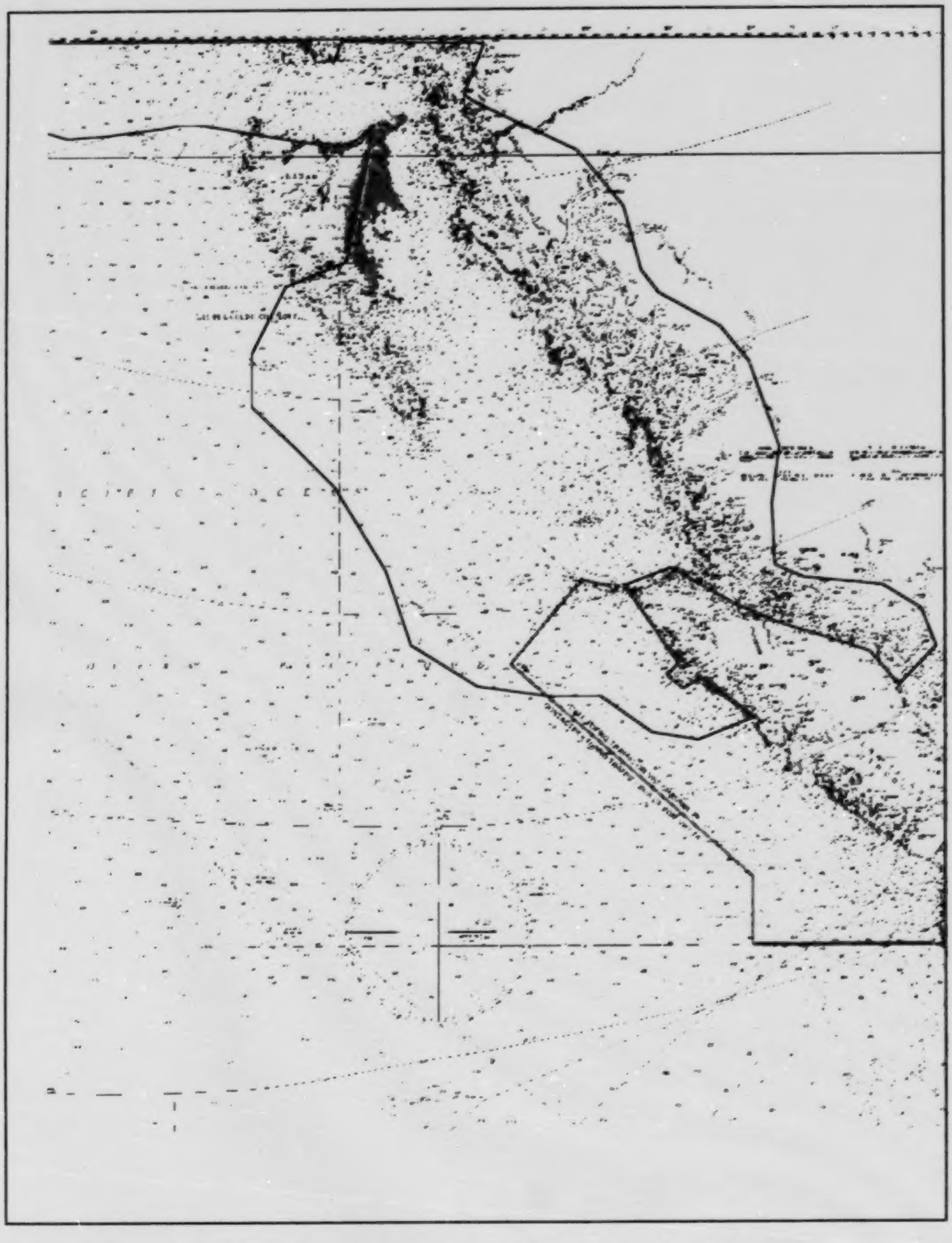

Figure 1 Zone of potential surface influence of spilled oil from the lease area during extreme winter weather.

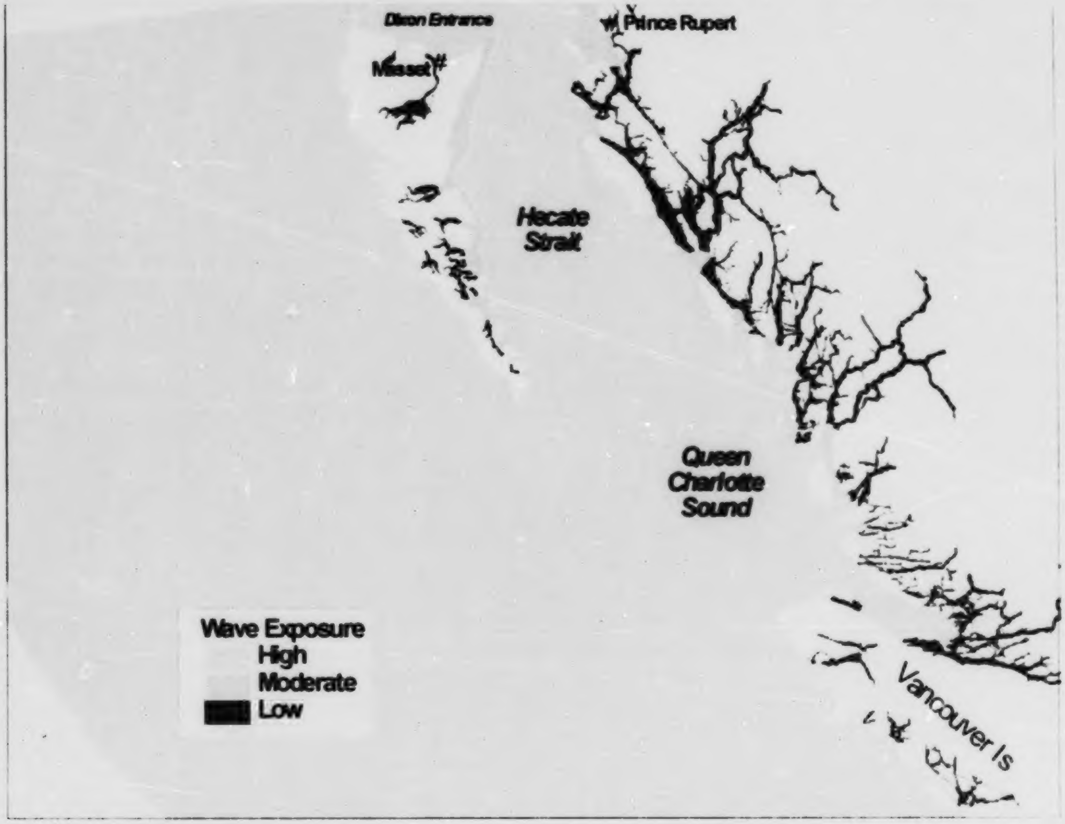

Figure 2. Generalized wave exposure categories of the North Coast (after Howes et al 1997). Low wave exposure areas have high potential for length oil residence (wavexp1.jpg).

Other Resources

This sensitivity assessment does not attempt a rigorous analysis of sensitivities of biological resources to spills but rather identifies some *types* of species at risk. Spill impacts occur at all trophic levels and direct mortality may not be the best index of overall effects. This assessment merely points out some of the species at risk and general information about these species that could be used to more quantitatively assess sensitivities.

Oil spilled at sea will weather in a variety of ways including photo oxidation, evaporation, dissolution and dispersion into the water column. The bulk of most spills remains on the water surface during the initial part of the spill. Organisms that spend most of their time living or feeding on the water surface are particularly vulnerable to spills. These include sea birds, shore birds and marine mammals. Most birds are highly sensitive to spill effects either through loss of insulation caused by direct oiling of feathers or by ingestion of oil from the preening of feathers. Many marine mammals are not as sensitive to oiling (e.g., seals, whales) but some, such as sea otters or fur seals are highly sensitive.

Of particular concern are high concentrations of species such as those that may occur around bird colonies, intensive feeding areas or seal pupping areas. For example, the Goose Group of islands in eastern Queen Charlotte Sound contains a unique population of sea otters; the entire population is contained in less than a 20 km^2 area. Significant portions of the population of ancient murrelets and Cassin's auklets (40 percent of the world's breeding population) nest on a few islands of the Queen Charlottes, making this particular species sensitive to "population"-scale impacts from a spill at the right time in the right area. The location of bird colonies and their approximate size is well known so the sensitivity of these resources should be "quantifiable". Offshore feeding areas are less well known, however, and there could be large aggregations of seabird along "fronts". The location of sea otter populations is generally well known and the sensitivities to spill impacts quantifiable.

Shore spawning areas for fish are a concern during spills. Anadromous fish pass through the nearshore zone enroute to spawning streams and some species, such as herring and pink salmon, spawn in the nearshore. Locations of anadromous fish streams are well documented as are commercial spawning areas of herring so that spill sensitivities for these commercial species are quantifiable.

Intertidal shellfish are potentially at risk from spills, although usually from sub-lethal effects rather than direct mortality. The distribution of commercial beds is well known but the distribution of non-commercial species is not well documented.

Fish are generally at lower risk from spill impacts than seabirds because they are beneath the water surface and oil concentrations are likely to be substantially lower. It is assumed that groundfish species that are concentrated near the shore would be most vulnerable to impacts. The Ministry of Environment (1983) shows substantial groundfish spawning areas in the vicinity of Dogfish Bank near eastern Graham Island but the nearshore of the entire *zone of influence* is probably utilized for non-commercial groundfish spawning. Generalized impacts such as these, as well as impacts to intertidal flora and fauna, can be estimated with the Provincial coastal sensitivity database, which is partially complete at the present time.

Mitigation Potential

There is the potential to mitigate impacts of spills by preventing oil from reaching the shorelines either through the use of dispersants or through protection booming. The use of dispersants, typically applied from aircraft, can be effective but is always controversial (see Ministry of Environment 1983, Appendix III) - dispersants are perceived by many as having significant impacts on fish and pre-approved dispersant use plans are required for rapid deployment in event of a spill (must be applied within 24 hr).

Containment booming of oil spills is not effective in high wave or high current areas, a substantial portion of the region in question. Even in low current and low exposure areas, the remoteness of most of the coastline from response centres would result in longer than 48 hr response time. It is unlikely that any more than a very small portion of the coast could be protected by booming in the short term (48 to 72 hr).

Dispersant application within 24 hr of the spill represents the only reasonable mitigation strategy. However, having a pre-approved dispersant application plan cannot be assumed as dispersant use is highly controversial. At present there is no pre-approved use of dispersants anywhere in Canada.

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Appendix 12: Introduction To The British Columbia Coastal Resource Programs[10]

Program Overview

The Province of British Columbia (BC) has been involved in the management of coastal resources since the 1800's. Today, the provincial government is responsible for the management of over 29,500 km of shoreline and seabed in the inshore and nearshore waters of BC, and works with other levels of government on the management of resources under federal and local jurisdiction.

BC has developed a number of coastal resource programs in support of initiatives to address economic development and diversification, coastal threats, land and resource conflicts, First Nations issues, and to support informed decision making in the coastal zone.

Many of BC's provincial coastal inventory and analysis programs are managed by Decision Support Services (DSS) of the Ministry of Sustainable Resource Management. Given the multi-jurisdictional nature of coastal environments, DSS has been tasked with the co-ordination of coastal resource, inventory, analysis, and certain policy development programs.

This summary provides a brief overview of coastal resource programs in BC, and where to get further information on each of these programs. Detailed summaries of these programs are under development on the DSS website at srmwww.gov.bc.ca/dss.

Program Components

Coastal Inventory and Information Management

Information is fundamental in developing any comprehensive coastal planning or resource application. BC has been collecting coastal resource data in a systematic and synoptic manner since 1979. Resource information is collected using peer-reviewed provincial Resource Inventory Committee Standards which include standards for data management and analysis. Types of environmental resource information collected includes oceanographic, physiographic, and biological data. Examples of human-use information collected includes data on fisheries, traditional knowledge, coastal tenures and land uses, and recreation and tourism use and capability.

Coastal resource information is stored in the Coastal Resource Information Management System (CRIMS). This system is used to provide data and analyses for coastal resource management, conservation, protection and planning applications. Key components of this system include, data management, access, analysis, and the design of resource models to develop products for conservation, planning and resource management. The CRIMS currently consists of several integrated technologies including GIS and image processing software, digital video, and attribute data management system and a trajectory model (for oil spills). These different technologies have been integrated into a single system that is accessed through a custom designed user interface.

Oil Spill Planning and Response

The CRIMS system described above is also a key component in BC's oil spill response and countermeasures program. DSS works closely with the petroleum industry to develop oil spill response and countermeasure strategies for the BC coast. These strategies include the development of the BC Biophysical Shore-zone Mapping System, which involves the systematic mapping of the coast to document the biophysical character of the shore zone. The underlying concept of the system is that the shore zone can be divided into discrete shore units on the basis of its physical character. The basis of the system is a shore unit, which identifies an area where the morphology (shape), sediment texture and physical process do not vary across or along the shore. Each shore unit can be further subdivided into components that are continuous across- or along- shore and are described in terms of their physical characteristics (morphology, sediment texture, dominant processes etc.). This physical system provides the framework for recording the biological character (e.g. species distribution and abundance) of each shore unit. This approach assumes the physical parameters of substrate, elevation and wave energy, as determined in the physical mapping are the main determinants of species distribution.

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[10] By Mark Zachiarais, British Columbia Ministry of Sustainable Resource Management.

Oil spill response and countermeasures atlases have been developed for the west coast of Vancouver Island, the southern Strait of Georgia, and Burrard Inlet (underway) which provide information on coastal biophysical and human use resources and the sensitivity and vulnerability to both oiling and clean-up of these resources.

Marine Protected Areas Strategy

BC currently has 104 provincial and 19 federal Marine Protected Areas (MPAs) which comprise about 4.2% of BC's waters less than 1000 m deep. DSS has developed a number of planning products to advance efforts to establish new MPAs and provide information for enhanced management planning of existing MPAs. These planning products include;

The British Columbia Marine Ecological Classification (BCMEC), which is a hierarchical marine classification consisting of four nested divisions based on physical properties, and a fifth division based on current, depth, relief, substrate, salinity, slope, stratification, temperature and wave exposure. The fifth division – termed ecounits - was created at a considerably larger scale (1:250,000), and is the first example of a large-scale marine classification applied over a large area (453,000 km2). The ecounits were developed to evaluate the boundaries and homogeneity of the four larger divisions, as well as for the application to coastal management and marine protected areas planning.

BC has also developed a preliminary list of Valued Marine Environmental Features (VMEFs), which are key features of marine environments valued for their conservation (i.e. natural environment), recreational and cultural-heritage characteristics. Identification of VMEFs was based on a detailed and multi-disciplinary literature review along with discussions with experts in marine sciences, recreation and cultural-heritage resources. Examples of the various types of VMEFs include:

Kelp beds - conservation VMEF

Abandoned canneries - recreation VMEF

Archaeological sites - cultural / heritage VMEF

BC has also been working on developing a MPA GAP analysis to identify representative and distinctive potential candidate areas for conservation. This work is based on the BCMEC, the VMEF work, and the identification of biophysical and human use values within existing MPAs. This work is also being used to identify existing provincial protected areas which may benefit from fisheries closures using federal legislation.

Coastal Planning, Management, and Monitoring

Since the early 1990's, the province has been using a land use planning framework to resolve land and resource use issues on terrestrial lands, and to assist in implementing the Protected Areas Strategy and Forest Practices Code. A primary emphasis has been on strategic level plans for regions and sub-regions, which then provide direction to more detailed, localized management or development planning.

The province has also initiated a number of integrated, consensus-based coastal management plans at both the strategic and local scales. At present, approximately half of the provincial coastal zone has been zoned by coastal planning, and plans are underway to complete coastal planning throughout the province.

To aid in the ongoing management of coastal environments, the province has initiated the development of a methodology to identify Marine Sensitive Areas (MSAs). MSAs are identified by using systematic intertidal and subtidal inventories to delineate sensitive and vulnerable habitats. The province has currently completed an intertidal MSA methodology and is currently developing a subtidal and offshre MSA methodology.

The province is also developing a trends monitoring program to evaluate environmental trends in the coastal zone as well as the effectiveness of coastal planning and MPA establishment efforts. These efforts are supported by Fisheries and Oceans Canada, Parks Canada and the Department of Natural Resources, Washington State.

Appendix 13: List of Some Comments and Questions Linked to Categories in the 2001 Whitford Report[11]

Comments and questions in this document are prepared in a shortened form (bullets) to highlight some issues related to BC offshore oil and gas development that may need additional attention or research. This document was not intended to be comprehensive.

Presentation/format: Information/action sheets

There is a need to more clearly identify the most important issues/topics to determine "whether BC offshore oil and gas resources can be extracted in a way that is scientifically sound and environmentally responsible".

Need a list of the key issues/topics and subtopics
Many of these issues are discussed in the Whitford Report
Are there additional issues/topics?
What are the issue/topic inter-linkages?

The clarification could include short information/action sheets (example in Appendix A) that list key information such as:

1) current background information (in bullets) relevant to the issue/topic
2) current issues and concerns
3) images, graphs, charts, maps, etc. that discuss/display the most important aspects of the issue/topic
4) expertise that can address the issue/topic, and research that has been completed, is in progress, is planned, is being thought about, and is needed in future
5) training and employment opportunities
6) priorities, timing, costs, benefits & problems:
    How important is the issue/topic (high, medium, low)?
    When does the issue need to be resolved or the topic need to be addressed (before moratorium is lifted, before exploration begins, during exploration or production, before or after decommission, etc.)?
    What are the $ costs?
    What are the benefits of each issue/topic?
    What are the consequences of not doing anything related to the issue/topic?
7) questions
8) and actions that need to be taken.

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[11] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Marjorie Johns, November 2001.

By building these information/action sheet-sets, an information resource can be developed. In future, it can be used (part or whole) for reference, presentations, or to build other documents such as an atlas on BC offshore oil and gas resource topics/issues (that could include information from the earliest planning, information, and research stages through exploration and development to decommission). An initial list of possible maps and images are included in Appendix C.

General comments and questions:

- **BC Offshore basins:** - should include the Queen Charlotte, Tofino, and Georgia Basins. The focus has mainly been on the Queen Charlotte Basin (potentially being the largest producer) but the Tofino and Georgia basins also have resource potential (see 2001, Hannigan et al., "*Petroleum resource potential of the sedimentary basins on the Pacific Margin of Canada*", GSC Bulletin 564).
    - Is gas or oil more important to produce or do they have equal value within the BC Offshore basins?
    - Locally and globally, what are the biggest markets for gas and oil?
    - If the offshore basins develop and produce, how will this change other BC and Canadian production?
    - Is there any new or old data that indicates where BC offshore exploration may begin?
    - Recommended local contact: Dr. Michael Whiticar, University of Victoria. He has compiled an excellent presentation on BC offshore oil and gas.
- **Expertise, research and training:**
    - Who are the experts that are needed to undertake research, provide information, data and results, monitor industry activities, and develop policies, regulations, and legislation, etc. (academia, government, industry, consultants, public, others)?
    - Who is currently available to provide up-front data and information?
    - Who needs to be hired or appointed (governments, academia, industry, etc.)?
    - What research has been completed, is in progress, and is planned?
    - What research programs are currently addressing some of the issues/topics (e.g. Coasts Under Stress Project: contacts Drs. Rosmary, Ommer, Chris Barnes, Harold Coward, Univ. Victoria)? Additional research and funding could be important for this project and others.
    - What research needs to be started and when can it be completed?
    - What training is needed?
- **Obtaining current and relevant information**
    - What is the best way to obtain current and relevant information from experts (interviews, requests for proposals, public forums, etc.)?

  - A literature review is good for finding completed research/reports but is missing active research/studies and proposals and ideas for future projects.
  - Collaboration with topic experts is essential for learning about future directions, needed research, and new project ideas.

- **Need for baseline information on:**
  - Basin geology, faults, and sedimentology
  - Oceanography and climate
  - Marine life, habitats, and distributions (we need baseline information to know what life is currently there - to be able to assess later the effects on the environment if there was a contaminant release or spill, or other damage).
  - Technology, engineering, and expected use of an area by the industry
  - First Nations peoples
  - What will happen to BC coastal communities with O&G development
  - Regulations, policies, legislation

- **Industry**
  - What industries are interested in the BC offshore O&G development?
  - What are the needs of industry?
  - What are industry's biggest risks, concerns, or limitations?
  - Do new technologies need to be developed?

- **USA's interests**
  - What are the USA's interests?
  - How would BC O&G industry effect trade with the USA?
  - Would the USA provide some funding support for research, training, or technological development?

- **Timing:** should the lifting of the Moratorium or the start of O&G development be timed according to BC, American, or Global O&G greatest demand?

- **Terrorism, protestors, other attacks**
  - What are the risks?
  - Are there preventative measures that can be taken?
  - How much does publicity and media attention increase the risk?
  - How can negative activity or media attention be redirected in a more positive manner?

- **Revenue & profits**
  - What is the best way to apply profits from BC offshore O&G production?
    medical
    education
    technological development to reduce emissions causing global warming

development and conversion to other fuel technologies less harmful to the environment (e.g. hydrogen fuels, Dr. M. Whiticar, UVic, Nov 2, 2001 presentation)

engineering to produce safer tankers, pipelines, or platform structures

others

◆ **Presentations**

- How much and what type of information, and when should it be presented to the public and others?
- There is a need for a more graphic style of presentation to include many images (figures, charts, maps, etc.) - whether it is in a report, poster, brochure, or seminar. Condense and filter information to the most important issues. Many viewers/readers (most?) would look first at an image, then short text, and lastly a lengthy document.

List of some comments and questions linked to categories in the 2001 Whitford Report

Comments and questions linked to categories in the 2001 Whitford Report			
category	**contents**	**page**	**comments and questions**
Introduction	1.0 & Fig. 1.1	1-2	Map and text should include all BC coastal & offshore wells drilled in the Queen Charlotte, Tofino and Georgia Basins.
Regulatory regime	2.0 to 2.3.6	5-23	Consider developing clear and precise industry guidelines that step through the application and regulatory process (through all Gov't departments). Order the process so that meeting the guidelines is "streamlined" and efficient. No Gov't red tape & delays to industry if the order and guidelines are followed. Give an accurate time estimate to industry for the application review and approval/rejection process.
Regulatory regime	2.0 to 2.3.6	5-23	Be clear on how regulations will be monitored and the monitoring agencies that are involved.
Regulatory regime	2.0 to 2.3.6	5-23	Consider safety regulations regarding rig blow-out, fire, spills, etc. Determine fastest speed of shutdown and what on-site & nearby equipment is available to reduce environmental hazards should an accident happen. Develop prevention & safety regulations.
Regulatory regime	2.0 to 2.3.6	5-23	Develop safety and design regulations to minimize hazardous spills for tanker transport & product transfer. (double-triple hulls?)
Regulatory regime	2.0 to 2.3.6	5-23	Should regulations be developed to keep O&G platforms and tanker/shipping travel away from environmentally sensitive areas?
Marine Coastal Biodiversity	3.1.1.	23	Conway, K.W., Barrie, J.V., and Neuweiler, M. June 2001. Hexactinellid sponge reefs on the Canadian continental shelf: a unique "living fossil". Geoscience Canada, v. 28, no. 2, p. 71-78. Should all or some of the sponge sites referred to in Figure 8 be protected? Are there other sites?

Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	Need more information on marine microorganisms, plankton, benthos, and the algae that are the foundation of the ecosystem - feeding those higher up on the food chain. Need maps and distributions.
Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	More current literature may be available on BC fishes and potential declines from fishing, climate changes, and habitat or food source loss. Present more data?
Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	Need maps and graphics illustrating the distribution of each marine life that may be effected by the O&G industry. It should include habitat and feeding distributions on coastal BC. How much knowledge do we have on BC marine life distributions? There are many marine life topics/issues from microscopic life to mammals.
Marine Coastal Biodiversity	3.2.7	29	Need a map showing existing aquaculture sites. Is the main concern protection of these sites if there was an oil or chemical spill near by? What precautionary measures could be taken to prevent contamination in an emergency/accident situation?
First Nations	3.3 & Fig. 3.1	30-33	Need map(s) and images showing key marine areas of interest to the Coastal First Nations peoples that are traditionally important for food resources, culture, etc. Can these areas be importance rated (critical/continuous, moderate, low/occasional use)? Categories could include intertidal, nearshore, and shelf to open marine. First focus on the Queen Charlotte & Tofino Basins.
First Nations	3.3 & Fig. 3.1	30-33	What is the extent of the "territorial seas of our people" (Deborah Jeffrey, Tsimshian Tribal Counsel, Press Release, May 14, 2001)? On what basis is this claim made? How is this claim/statement interpreted by Gov't?
First Nations	3.3 & Fig. 3.1	30-33	Do we need further research and mapping to show sea level changes over the last 10,000-13,000 (or more) years within Queen Charlotte and Tofino Basins to indicate potential areas that may have been used by First Nations? Some work has been completed by Josenhans, Fedje, Barrie, Conway, & others. Further studies are in progress within the "*Coasts Under Stress Project*" (contacts: Drs. Rosmary Ommer, Chris Barnes, Harold Coward, Univ. Victoria).
First Nations	3.3 & Fig. 3.1	30-33	Are the First Nation's main concerns: oil/chemical spill risk and the effect on marine resources & fishery, cultural changes from industrial development, and tourism? Other issues?
First Nations	3.3 & Fig. 3.1	30-33	What do the First Nations want? (see Chief Gay Reece, Lax Kw'alaams First Nation speech). Proof that there is no or minimal risk from oil/chemical spill or environmental damage? What is the minimum level of risk that is acceptable? What are the priorities to settle land claims and how does this relate to marine resources? What do First Nations want with respect to employment, revenue sharing, role in decision making, and active participation up-front? Where is there room for compromise or negotiation? First Nations participation up-front appears to be very important.
Communities	3.4	33-38	A map & images showing communities/districts would be useful. Also, include Tofino Basin communities.

Communities	3.4	33-38	Include a section with an example community (E.Coast Canada?) that shows changes within the community after introduction of the O&G industry through to decommission. What is at stake for a community? How does the new O&G industry effect original industries & resources? What happens with schools, health & facilities, housing, etc.? Are the human resources there? Jobs and training, retraining? Influx of new residents? Many of these topics are being looked at in the *"Coasts Under Stress Project"* (contacts: Drs. Rosmary Ommer, Chris Barnes, Harold Coward, Univ. Victoria).
Communities	3.4	33-38	How receptive are these communities to change? Is the timing good following a decline in other resource industries?
Other Resource Use: Tourism, sensitive areas, ports, shipping	3.5	38-44	Have there been any studies on the visual effect on tourism of a drilling platform in a "natural" or "marine wildlife" environment? Is the drilling platform a true "eye-sore" or does it provide some curiosity and intrigue - becoming a tourist attraction itself? Can we find an example of a drilling platform off a nature park somewhere in the world? Dr. Chris Barnes (UVic) mentioned to me one that is located off a park in New Zealand. This might be an excellent example especially since it also is in a tectonically active area.
Other Resource Use: Tourism, sensitive areas, ports, shipping	3.5	38-40	Cruise ships also may be considered an "eye-sore". These ships are a large man-made structure that contributes wastes and pollution to the environment in addition to wave wash to the shorelines.
Other Resource Use: Tourism, sensitive areas	3.5.2 to 3.5.3.3	40-44	Need a map & images showing each of the BC marine parks and sensitive areas. Rate areas according to importance/sensitivity. Also, include land and resource management plan areas.
Shipping	3.5.4	44	What statistics does BC have on shipping accidents and environmental damage (especially from large ships)? Would having a Port Authority pilot on each tanker and ship within BC waters improve safety and accident risk? Is shipping of O&G an industry requirement? Can it be achieved safely through an underground pipeline in a tectonically active basin (global examples)?
Physical Environment: Bathymetry	4.1.1	46-48	Canadian Hydrographic charts: how outdated are these charts? Are there dangerous features (for larger ships or pipelines) such as in actively changing areas (Rose Spit? others?) that need to be chart-updated? How important is it to update BC coastal charts? Can a map be created illustrating and rating the need for chart updates especially in areas of interest for O&G exploration?
Water level & ocean currents	4.3	50-53	Do BC waters demonstrate any more severe tidal and current conditions than other O&G structure locations in the world? What is the worst tide & current scenario for BC coastal waters?
Ocean currents, waves, wind	4.4	54-59	How much additional research is needed to better understand ocean currents and where an oil spill (or other contaminant) may travel should an accidental occur? How important is it to have knowledge on ocean currents for winter months? Is it possible to collect ocean current data during winter months? Is a contaminant spill in winter/storm months less damaging? (Does it disperse faster in greater wave action?)

Weather forecasting	4.4.4	59-62	Confirm that a 6 hour weather warning is sufficient to shut-down & lock-up a rig/platform in preparation for a storm. What is the minimum time for secure shutdown?
Gas Hydrates	4.5	62	Additional references (G. Spence, UVic)? What is the potential resource estimate of gas hydrates in offshore BC? Need a map illustrating gas hydrate locations.
Faulting & earthquakes	4.6	62-64	Recent literature updates on faulting, etc. Rohr & others (1992, 1995, 1997, 1999, 2000). Contact K. Rohr at UVic.
Faulting & earthquakes	4.6	62-64	Can a platform be built to withstand a magnitude 9-10 earthquake and associated ground motion and acceleration? Need map showing ground & motion acceleration.
Faulting & earthquakes	4.6	62-64	Will BC offshore oil and gas extraction add or contribute a significant earthquake risk to the area? In other areas, there have been recorded earthquakes(up to M4.3) that may have resulted from hydrocarbon extraction, high pressure fluid injection, and/or subsidence.
Tsunamis	4.6.2	65	Need map showing areas where there would be tsunami wave amplification or dangers.
Geotechnical hazard areas	4.7	65-66	Need a map & images showing areas of sedimentological hazards (liquefaction, submarine slope instability, sediment gas, etc.) or where future studies need to be made to obtain data.
Sub-sea noise	table 5.1	79	A good table. Has any more current research or data been compiled in the 1990's?
Drilling Technology	5.2	80-90	What are BC offshore well site limitations? Is horizontal drilling a strategic option for the available resource? Can a well site be strategically placed away from an environmentally sensitive area and at what cost?
wastes & disposal	5.2	88-90	Where would sites for disposal of wastes, chemicals, hazardous materials, drilling mud, waters, etc. be located? How would it be monitored? How would fumes be filtered?
Blowout	5.4.3	95-96	If the largest USA offshore blowout was 11,500 barrels in 1988, can an appropriate and immediate spill containment apparatus be regulated/required for each platform (i.e. stored at the site or very close by)? What extra expenses would be necessary to have the equipment/supplies? Is it within an industry budget?
platform collapse or pipeline break			Need more details on the scenarios of platform collapse such as from an earthquake, tsunami, or storm and a pipeline break. What is the maximum chemical or fuel spill and how much environmental damage would follow? What would be the expected expense to industry, Government, others?
Atmospheric emissions	6.1.5; table 6.1	107-109	How do the amount of emissions from an O&G platform compare to other polluting sources (e.g. pulp & paper mill; Robert's Bank Port; BC Ferries (include vehicles); one day of Vancouver cars; etc.)?
pollutants	general		Perhaps one large table could be made including above and other pollutants to compare data from other industrial sites (BC & other?). It would be useful to have comparative data from other industries in Coastal BC.
seismic surveys	6.1.8	110-113	Need maps indicating the timing and distributions of Basin fishes, mammals & other marine creatures that would be most affected by seismic surveys.

seismic surveys versus drilling			At what level do seismic surveys stop and drilling begins? How extensive are gassy sediments in the BC offshore basins and how much do they limit the value of seismic surveys from "seeing through the "frosted glass window"? Have new technologies been developed to better filter and understand data in gas rich sediments? Would there be better value in drilling more exploratory/test holes?
geological resources			Need knowledge and maps on the location of mine/quarry resources (gravels, lime, other) and industry requirements for resource transportation.
Archival information			What information is available in the BC archives (or other) on previous BC offshore exploration and drilling? Are there any photos? Were there any accidents or spills? What was the equipment and worker resource? What communities were involved? What was the media and public response to these activities at that time?

List of initial maps and images which could be used to build a reference or atlas on BC offshore oil and gas development and environment.

BC Offshore Oil and Gas Development and Environment Atlas	
Topic	**contents & comments**
outline coastal BC & Can/USA borders	base map
land topography, rivers, lakes, etc.	base map
communities to cities, airports, port facilities, lighthouses, railways, etc.	maps and images - especially those relevant to O&G development
shipping/boating	map and images showing current typical shipping & boat use patterns/areas (e.g. tankers, cruise liners, cargo, lumber industry, fishing, pleasure, etc.). This shows current use and a certain level of risk for contaminent spills or other hazards.
parks & other environment designated areas	maps and images
First Nation's communities & reserves	Map 1: existing and past communites, Map 2: desired land claims; Map 3: land and marine areas/regions used by First Nations. Images showing nearshore and marine resource use.
weather	one or more maps & images showing weather patterns (including storms, seasons, and patterns such as El Nino)
marine bathymetry	maps and images that indicate areas of rapid change (e.g. Rose Spit erosion & transport, etc., areas of frequent slides/slumps, etc.)
tsunami hazard map	map indicating areas most sensitive to tsunami wave amplification
marine charts	subdivide into regions as per need of upgrade (may be based on year, urgency for upgrade such as seafloor change, or increased use assocated with O&G exploration or expected production).
geology of QCI & Vanc. Is. & coastal regions	overview geological maps & images

oil & gas basins/resource potential	Include previously drilled wells and those that may be target by industry in future. Provide some archival photos.
faults	indicate all known faults that may effect O&G industry
seismic surveys	showing all previous seismic surveys (or most important ones); Include relevant seismic data/results.
earthquake hazard	map showing magnitude & position of previous earthquakes (>M2.5?). Include hazard map.
marine geology	basin structure 1) understand stability for installation of drilling platform, underground pipelines, etc.; 2) geology for locating O&G; 3) location of possible in situ gas
marine surveys	showing core locations (e.g. GSC) that may provide data for future studies, show possible future sites
geological materials	source of gravels & other materials necessary for industry
aeromagnetic surveys	available data
sea level change to 13,000 years ago	Within the basins, provide maps showing past sea level drops that may have been significant to First Nation's peoples for travel across the region. Do they have a claim to these past lands now covered by marine waters?
ocean currents & hazards	several maps showing critical regions & timing; several model maps showing if there was an oil spill -where the oil would be transported.
oceanography	several maps showing marine temperature gradients, salinity, pressure, anoxia or other special conditions, etc.
Biology/ecology	multiple maps indicating critical/high use regions for each form of life from plankton to mammals (including marine plants) that may be effected by the O&G industry.
Biology/ecology cont.	Examples: plankton & micro-benthics, sponges, shellfish, other invertebrates, algae, fishes, birds, marine mammals (whales & dolphins, seals, otters, etc.) & others. Multiple species & genera may be involved.
Oil & Gas technology	Showing equipment and structures through various phases of design and building, exploration, development, production, and decommissioning. Compare to first drilling in offshore BC?

Appendix 14: Oceanographic Situation of Hecate Strait, BC[12]

Introduction

The Hecate Strait is situated between the BC mainland and the Queen Charlotte Islands centered around 53°N latitude and 131°W longitude (Figure 1). Although the Hecate Strait is somewhat protected from the Pacific Ocean by the Queen Charlotte Islands, the size of the water body (55 km to 120 km wide), its morphology and oceanographic and weather situation make it susceptible to severe conditions. The Dixon Entrance to the north and Queen Charlotte Sound to the south of Hecate Strait have oceanographic conditions somewhat different from the Hecate Strait.

Bathymetry

Figure 1 shows the water depth isobaths for the region. The majority of the Hecate Strait has relatively shallow water depths of 200m or less, and reaches up to 300m deep in the south. Much of the Queen Charlotte Sound is also shallower than 200m but reaches 400m in the troughs. The Dixon Entrance shallows from 400m to 200m landward, with the exception of the 35 m Learmonth Bank at the mouth of the Dixon Entrance.

The water depths in the Hecate Strait and Queen Charlotte Sound are commonly encountered in offshore petroleum exploration settings. As such, they do not present any technological restriction on the exploration for petroleum. For comparison with the east coast (Jeanne d'Arc Basin), the discovery well Chevron et al Hibernia P-15 (location: 46°44' 59"N, 48°46'51"W) was drilled by the Glomar Atlantic/Zapata Ugland from May 27,1979 to January 2, 1980 to a Total Depth of 4407m in 80m water depth. In the same Jeanne d'Arc Basin, the discovery well Husky/Bow Valley et al Whiterose N-22 (location: 46°51'48"N, 48°03'57"W; June 27, 1984 - January 4, 1985) was drilled to 4628m in 122m water depth.

Basically the morphology of the Hecate Strait is a shallow, broad shoal in the north with deeper troughs cutting channels along the mainland and towards the Queen Charlotte Sound. Three major troughs characterize the southern part of Hecate Strait and Queen Charlotte Sound as seen in Figure 1. The most northerly of the three traverses between the southern tip of Moresby Island and Middle Bank. The second trough cuts between Middle Bank and Goose Bank and the third trough is between Goose and Cook Banks.

On the western margin of the Queen Charlotte Islands, the shelf is very narrow; approximately 40 km in the north and 10 km to the south. Further west, the Pacific Ocean deepens rapidly to >2,500 m.

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[12] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

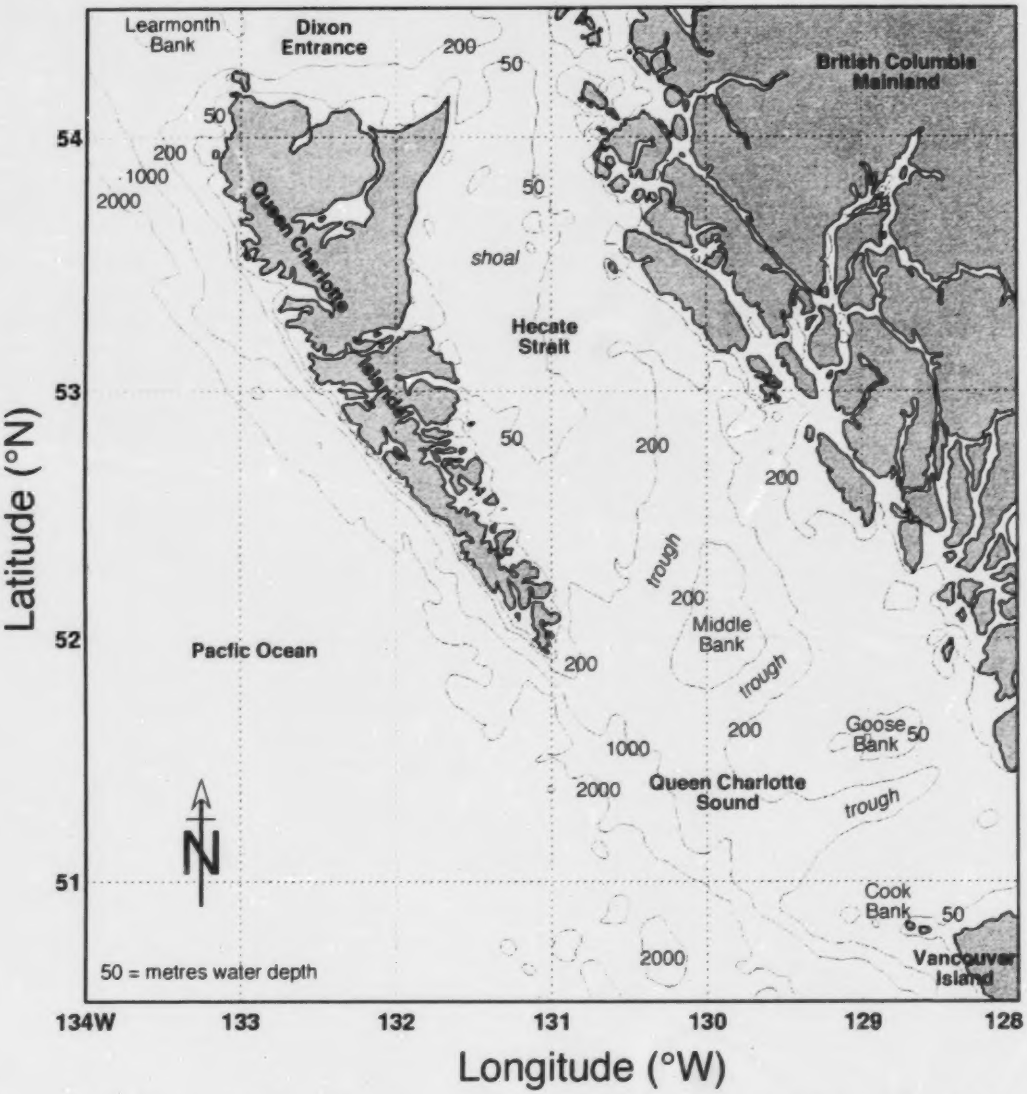

Learmonth Bank
Dixon Entrance
200
50
British Columbia Mainland
54
50
200
1000
2000
Queen Charlotte Islands
50
shoal
Hecate Strait
53
50
200
200
trough
200
Middle Bank
trough
52
Pacfic Ocean
200
200
Goose Bank
50
1000
2000
Queen Charlotte Sound
trough
N
51
Cook Bank
50
Vancouver Island
2000
50 = metres water depth
Latitude (°N)
134W
133
132
131
130
129
128
Longitude (°W)

Figure 1. Location map of Hecate Strait (Queen Charlotte Basin) showing the basic bathymetry (modified from W. R. Crawford, IOS-DFO)

Climate, Weather and Winds

The climate of the Hecate Strait can be characterized as a temperate climate with a strong westerly onflow of moist marine air. It is one of the areas of Canada with the strongest winds. Values of up to 200 km/hr have been recorded (Cape St. James). Due to topographic highs created by the coastal mountains, the winds tend to blow north and south along the axis of Hecate Strait. These winds are driven by seasonally changing surface ocean temperatures and barometric pressure systems. As discussed in detail below, the surface water temperatures in Hecate Strait can vary from 8 – 16°C in the summer to 4 – 9°C in the winter.

The air temperatures taken continuously over the past 50 years in the region display a much larger range that the water temperatures. For example, typical air temperatures on land in Massett are 18°C in the summer and 4°C in the winter. Average air temperatures over the water in the area seasonally vary about 9°C, with a mean temperature of 12°C in July and 3°C in January.

Despite the apparent mild temperatures, annually there are approximately 20 frost days in the region. The freezing and icing associated with this is recognized as a particular hazard of operations in the region, but do not pose any unusual conditions to those encountered in similar higher latitude onshore and offshore exploration and production operations elsewhere in BC, Canada and internationally.

For example in the Jeanne d'Arc Basin on the east coast (Grand Banks region), the temperature variations are larger and more severe. There the air temperature ranges from –17.3°C to 26.5°C, the surface water temperature ranges from –1.7°C to 15.4°C. In the Jeanne d'Arc Basin the thickness of icing (glaze and rime) is 72 mm (10 year maximum) to 169 mm (100 year maximum). Similarly, spray icing thickness in the region is 316 mm (10 year maximum) and 514 mm (100 year maximum).

Furthermore, there is a considerable number of iceberg sightings in the Jeanne d'Arc Basin area of operations (annual mean: 72, maximum: 169 on a one-degree grid).

The two barometric pressure systems are the North Pacific High and the Aleutian Low. The former dominates in the summer and generates northerly winds (ca. 30 km/h). The Aleutian Low is dominant in the winter months and creates southerly winds (ca. 50 km/h). Winds are strongest from October to February and are usually out of the south or southeast.

Month	Nov	Dec	Jan	Feb	Mar
Average Wind Velocity (km/h)	34	37	39	40	38
Highest Recorded Gust (km/h)	191	181	191	189	193

In comparison, the winds in the Jeanne d'Arc Basin on have 1-hour maxima of 120 – 157 km/h and 1-minute maxima of 139 – 167 km/h.

Rainfall in the region is also high with a considerable range from 80 on the eastern coast of Queen Charlotte Island to 400 cm/yr on the west coast. In Massett, the precipitation is ca. 100 cm/yr as rainfall and ca. 28 cm/yr as snowfall.

	Sandspit Airport	Cape Saint James
Average Rainfall (cm/yr)	135	154
Average Temperature (°C)	8.1	8.7

The weather is monitored by a system of land-based stations operated by the Meteorological Service of Canada, marine weather buoys by DFO and from the MAREP station.

Tides, Currents and Waves

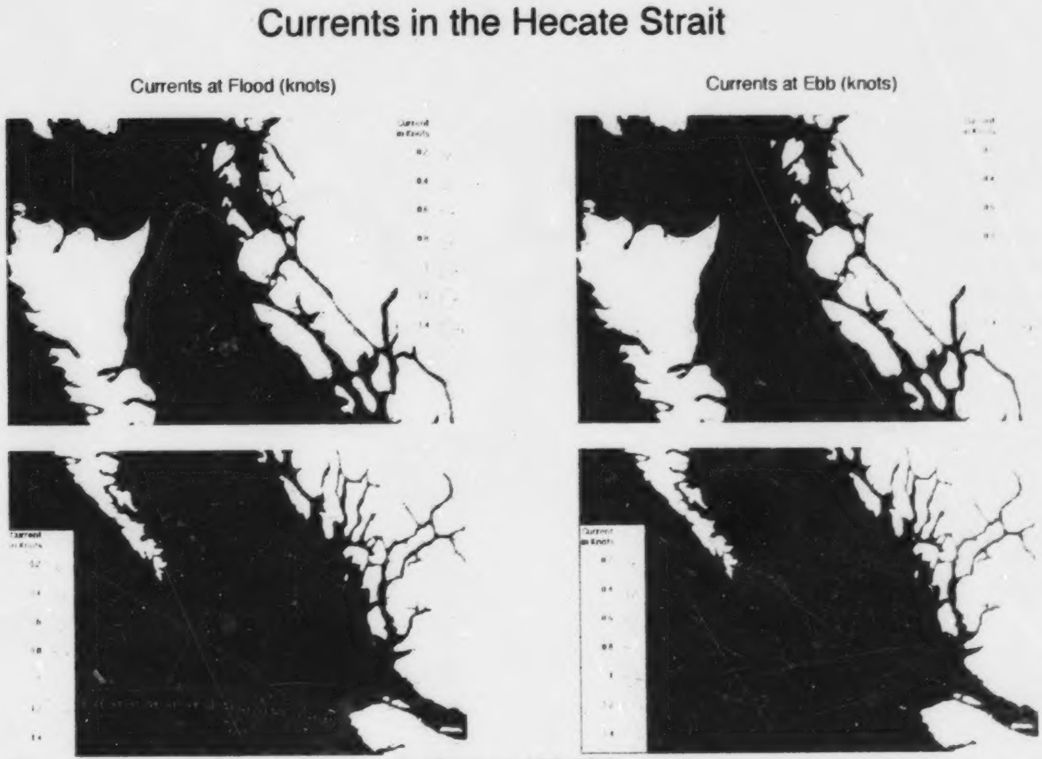
The Hecate Strait has two diurnal tides. The tidal range is smaller in the south (ca. 3 m) and increases to ca. 5 m in the central and north Hecate Strait. Some coastal regions have higher tidal ranges, e.g., up to 7 m at Prince Rupert. For comparison, the tides in the Jeanne d'Arc Basin region are significantly lower (ca. 0.5m above and below mean sealevel). Storm surges in this Grand Banks region do not contribute to significant tidal variations.

Currents in the Hecate Strait are driven by tidal forcing and by prevailing winds. Some coastal effects can also influence the local currents. Figure 2 shows the current directions and strengths for the Dixon Entrance, Hecate Strait and Queen Charlotte Sound during flood and ebb phases. During flood the water flows into Hecate Strait from the Dixon Entrance and Queen Charlotte Sound. During ebb, the situation is largely reversed. Typical surface current speeds are 25 – 50 cm/s (equivalent to 0.5 – 1 knot).

Local variations do occur, especially associated with land constrictions. For example, Figure 3 shows tidal currents up to 250 cm/s flowing around Cape St. James on the south tip of the Queen Charlotte Islands.

The bottom currents are somewhat lower, with typical values at 15 – 25 cm/s.

Wind-driven currents are less important than the tidal currents, but during intense storms wind-shear surface currents can attain values up to 25 cm/s.

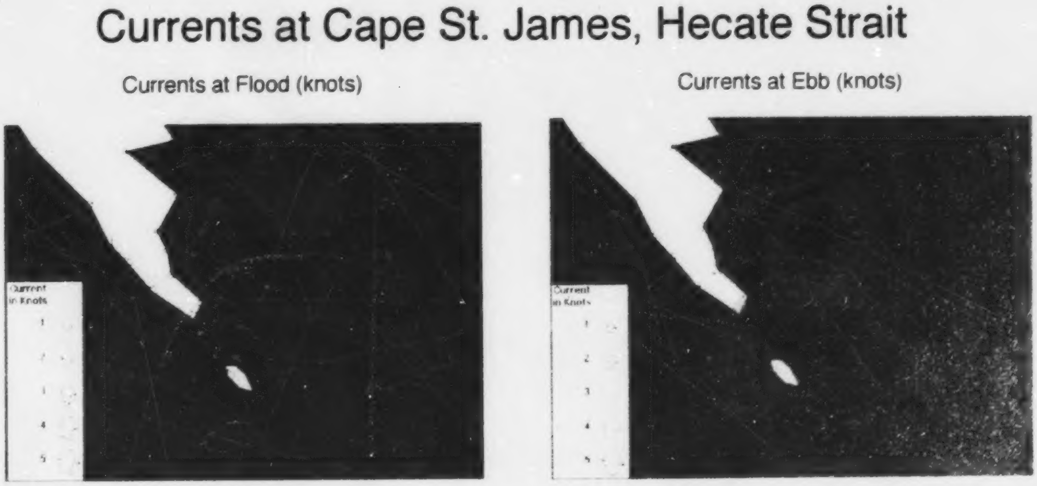

Currents in the Hecate Strait

Currents at Flood (knots)

Currents at Ebb (knots)

Current in Knots
0.2
0.4
0.6
0.8
1
1.2
1.4

Figure 2 Currents in Hecate Strait (from R. Thomson, IOS-DFO)


Currents at Cape St. James, Hecate Strait

Currents at Flood (knots)

Currents at Ebb (knots)

Current in Knots
1
2
3
4
5

Figure 3 Currents at Cape St. James, Hecate Strait (from R. Thomson, IOS-DFO)

In comparison, the currents in the Jeanne d'Arc Basin are somewhat lower than the Hecate Strait. In the Jeanne d'Arc Basin the surface currents are 7.5 – 8.0 cm/s at the surface (10m, 1 – 10 year period) and a 100 year maximum of 10 cm/s. In mid-water (25m and 75m) the currents are 6.0 – 7.6 cm/s and 3.0 – 6.0 cm/s, respectively. The corresponding 100 year maximum for these two water depths is 9.5 and 7.5 cm/s. At the sea floor (ca. 100m) the 1 – 10 year period currents are 1.5 – 3.2 cm/s and a 100 year maximum of 6.5 cm/s.

A series IOS, DFO current moorings are deployed in the region as shown in Figure 4. Together with IOS drifter studies, e.g. Figures 5 and 6, the surface currents are well studied in the petroleum exploration regions of Hecate Strait and the Queen Charlotte Sound. However, more site-specific bottom current studies are required.

Figure 4. Current mooring stations around Queen Charlotte Islands (from R. Thomson, IOS-DFO)

The strong winds in the Hecate Strait generate considerable waves and swells. The actual wave heights are dependent on the fetch, i.e., the proximity to sheltering land, and on the water depth. Pacific Ocean swells influence much of the lower part of Hecate Strait and the Queen Charlotte Sound. During storm events the sea state can increase to over 10 m. Waves of 20 – 30 m have been recorded in the strait. Of particular concern is the rapidity with which the seas can increase, often within hours.

Wave heights in the Jeanne d'Arc Basin, which has experienced substantial exploration and production activities, are very similar to the Hecate Strait. In the Jeanne d'Arc Basin the significant wave height is 11 – 14 m (1 – 10 year report), and a 100-year value of 17.5m. The corresponding maximum wave heights are 20.9 – 30.4m (1 – 10 year) and 30.4m (100-year).

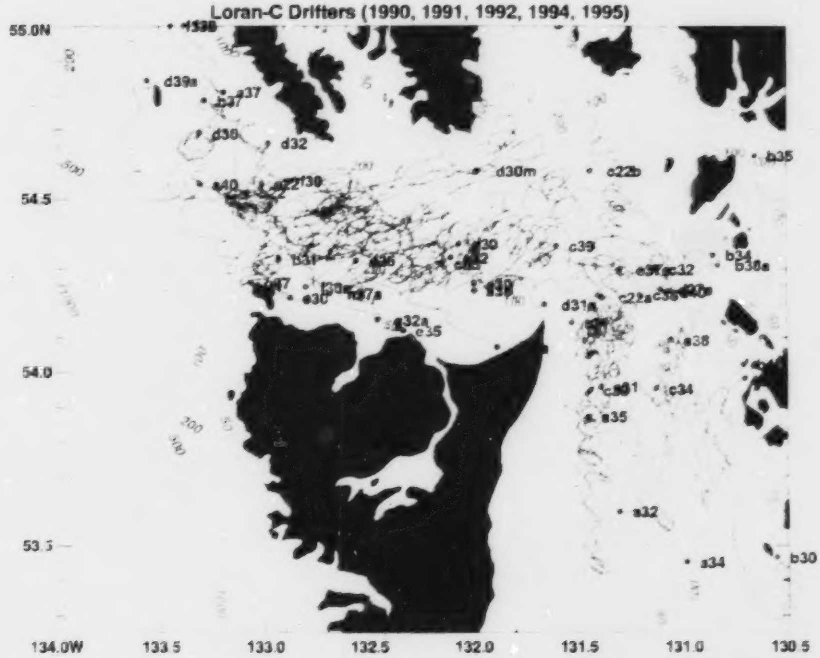

Loran-C Drifters (1990, 1991, 1992, 1994, 1995)
55.0N
54.5
54.0
53.5
134.0W
133.5
133.0
132.5
132.0
131.5
131.0
130.5
d39a
a37
b37
d36
d32
d30m
c22b
b35
a40
c39
b34
b36a
d31a
a38
c34
a35
a32
a34
b30
a32a
c35

Figure 5. Example of current drifter tracks in Dixon Entrance and northern Hecate Strait (from R. Thomson, IOS-DFO)

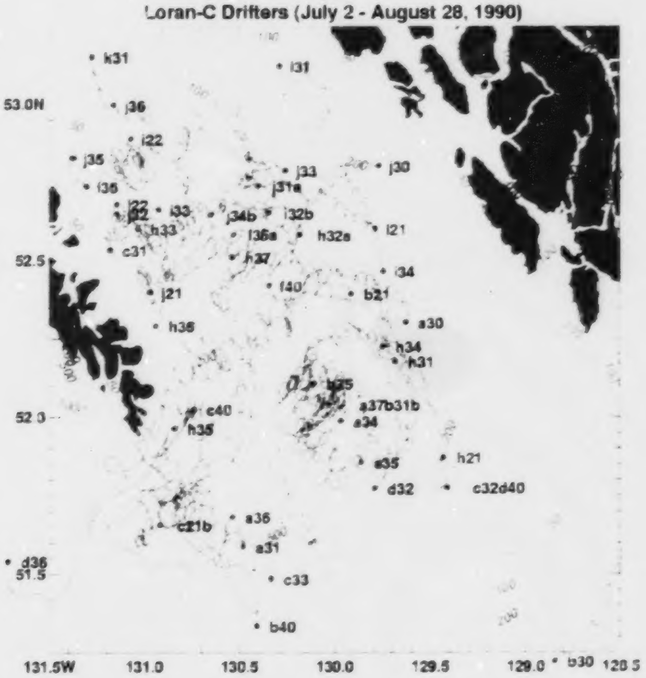

Loran-C Drifters (July 2 - August 28, 1990)
53.0N
52.5
52.0
51.5
131.5W
131.0
130.5
130.0
129.5
129.0
128.5
h31
i31
j36
i22
j35
i36
j33
j31a
j30
h33
j34b
i32b
c31
i36a
h32a
i21
h37
i34
j21
i40
b21
h36
a30
h34
h31
b35
a37b31b
c40
a34
h35
a35
h21
d32
c32d40
c21b
a36
a31
d36
c33
b40
b30

Figure 6. Example of current drifter tracks in southern Hecate Strait and northern Queen Charlotte Sound (from R. Thomson, IOS-DFO)

Water Temperature

The water temperature depth structure in Hecate Strait have been observed during cruises to the region by the DFO Institute of Ocean Sciences. Figure 7, is a generalized depth plot of the water temperature in the Hecate Strait and Queen Charlotte Sound (data from W.R. Crawford, DFO, IOS). Below the uppermost 50m the temperature varies little between 4 and 8°C. Actual variations at a specific locality can have even less range. The local temperature depth distributions (3, 50, 100, 200m and bottom water) is shown in the vertical series isotherm maps (contours of equal temperature) for the region (Figures 8 and 9).

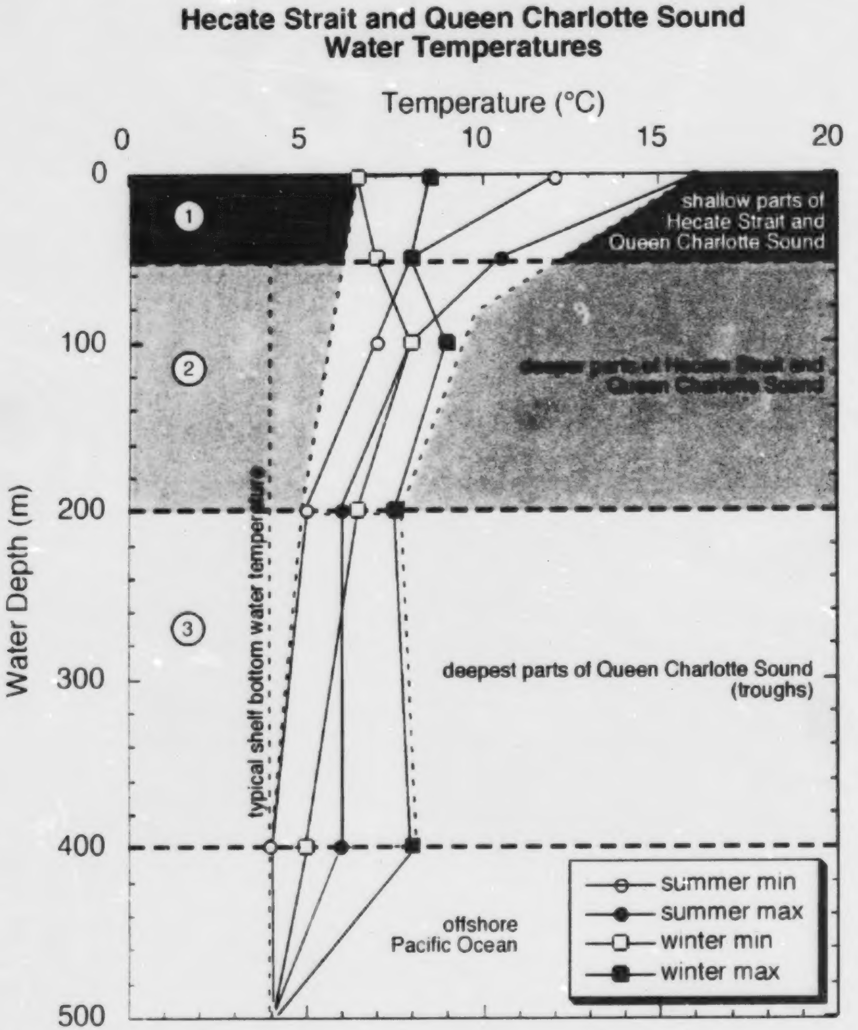


Figure 7. Water temperature profiles (maximum and minimum temperatures) for summer and winter months (data W.R. Crawford, DFO, IOS)

Summer Water Temperature and Salinity at Specific Depths in Hecate Strait

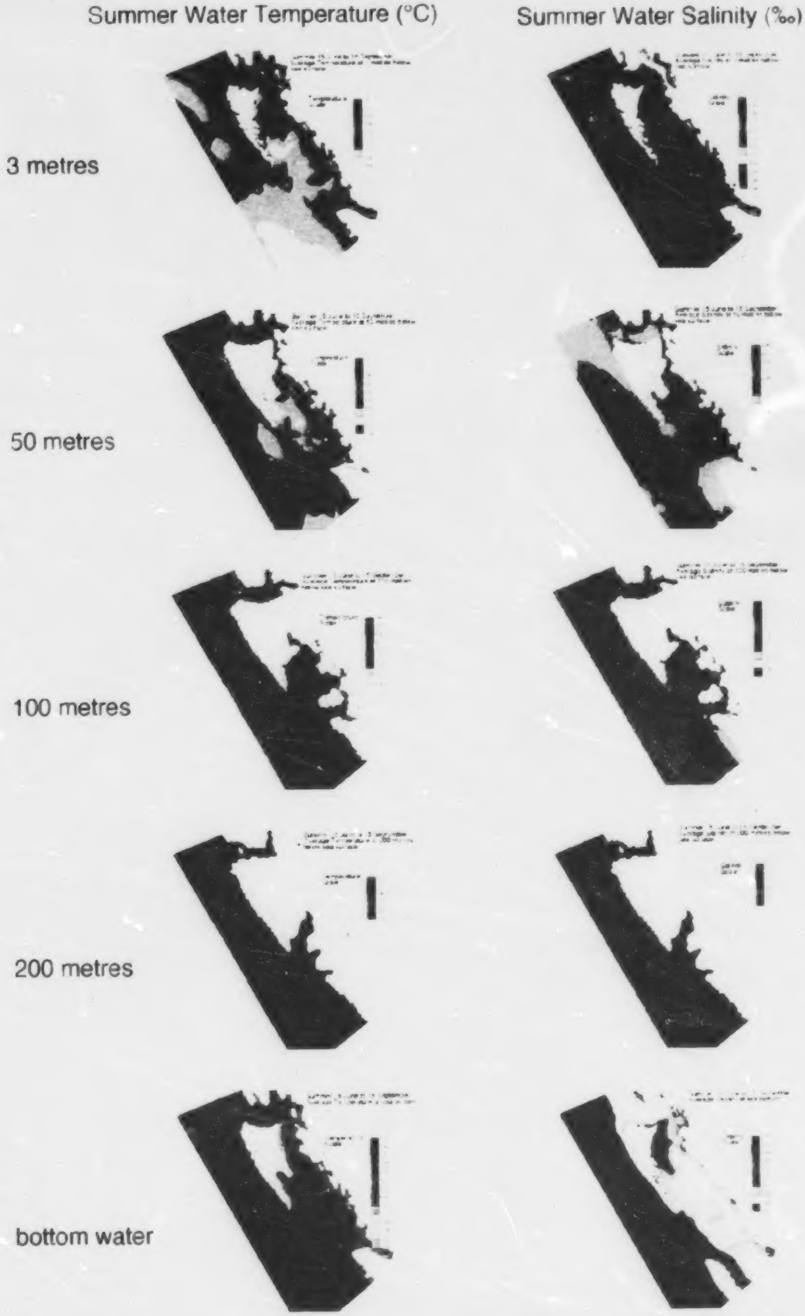

Summer Water Temperature (°C)
Summer Water Salinity (‰)
3 metres
50 metres
100 metres
200 metres
bottom water

Figure 8. Summer temperature and salinity contour maps at selected depths in Hecate Strait and Queen Charlotte Sound (data W.R. Crawford, DFO-IOS)

Winter Water Temperature and Salinity at Specific Depths in Hecate Strait

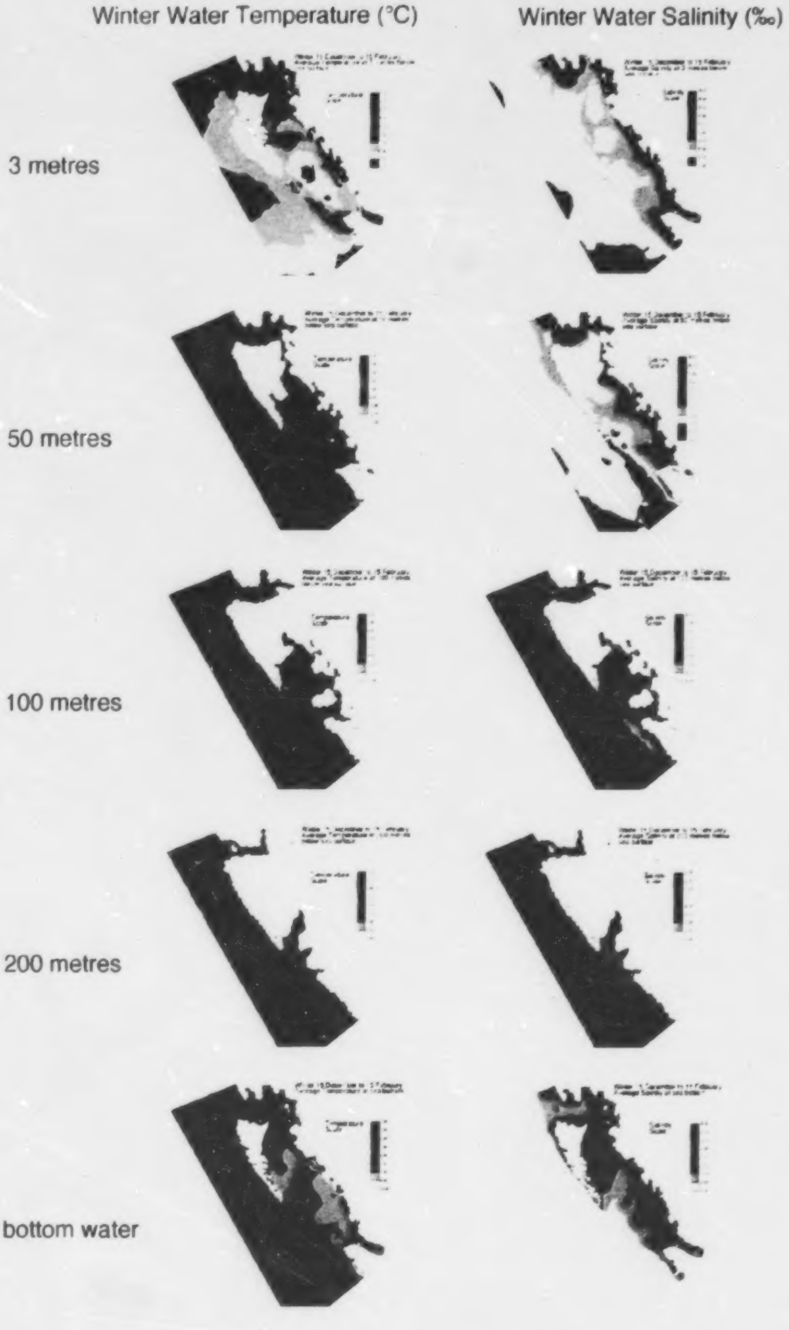

Winter Water Temperature (°C)
Winter Water Salinity (‰)
3 metres
50 metres
100 metres
200 metres
bottom water

Figure 9. Winter temperature and salinity contour maps at selected depths in Hecate Strait and Queen Charlotte Sound (data W.R. Crawford, DFO-IOS)

Regionally the water temperatures can vary from 8 – 16°C in the summer to 4 – 9°C in the winter, with most of the range in the surface waters that vary from 6 – 16°C (Figure 7). These relatively mild and constant water temperatures strongly moderate the regional climate.

In comparison on the east coast in the Jeanne d'Arc Basin (Grand Banks region), the temperature variations are larger and much more severe. There the air temperature ranges from –17.3°C to 26.5°C, the surface water temperature ranges from –1.7°C to 15.4°C and the sea bottom temperature ranges from –1.7°C to 3.0°C.

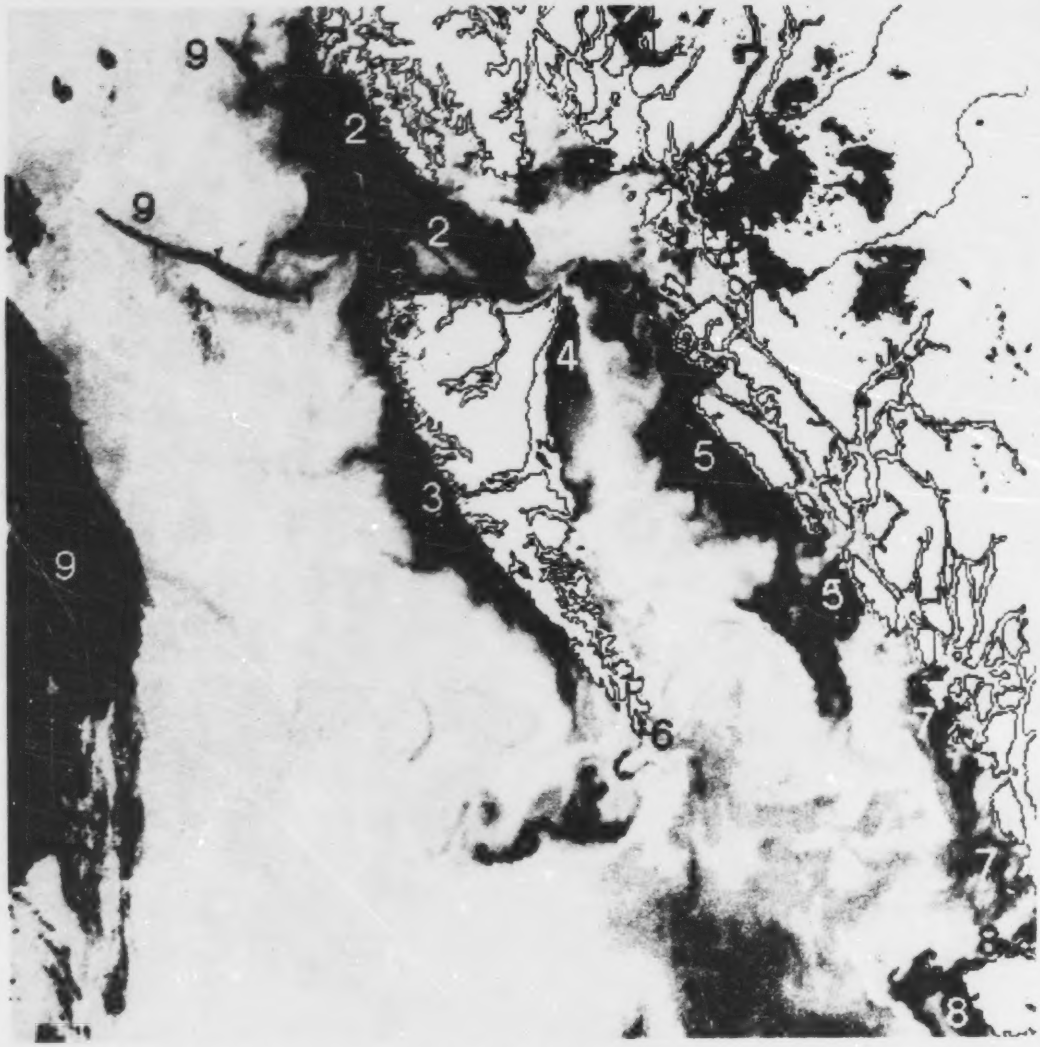


Figure 10. Summer surface water temperature (after Gower and Wallace, 2001) Cool water (10°C appears blue, warmer waters are in red, ca. 16 °C).

Figure 10, from Gower and Wallace (2001) shows a US National Atmospheric and Oceanic Administration (NOAA) satellite image of the summer surface water temperature in the Queen Charlotte Island region (24 July 1994, near 6:00 Pacific Daylight Time. The cooler temperatures (ca. 10°C) plot as dark areas in the figure whereas the warmer regions (16°C) plot as lighter areas. At the time, the winds were from the northwest. The numbers indicated in the figure correspond to the areas of local interpretation by Gower and Wallace (2001). For information purposes their interpretations are cited verbatim below

[1] Chatham Sound and Skeena River Plume in Northern Dixon Entrance

Fresh water from the Skeena River mixes with salt water in Chatham Sound. and flows out of Chatham Sound as a five metre deep layer of brackish water. Sediments in this water absorb light, which warms this layer as it flows northward out of the Sound, then westward across Dixon Entrance. Any brackish water that flows out of Chatham Sound through channels to the west passes through narrow channels with strong tidal currents that mix deep cold water up to the surface, and cool this layer.

[2] Western Dixon Entrance and the Southern Alaskan Panhandle

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from Alaskan shores. This waters are replaced at shore by colder deep water that upwells to the surface, and is blown into Dixon Entrance when the northwest winds are especially strong.

[3] West Coast Queen Charlotte Islands

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from west coast of the Queen Charlotte Islands. Waters that move away from the coast are replaced at the ocean surface by deeper colder water all along the west coast of Graham Island and much of Moresby Island.

[4] Dogfish Banks

Waters here are generally 10 to 20 metres deep, much less than in other areas, and are also the warmest in summer.

[5] Eastern of Hecate Strait

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from the mainland side of Hecate Strait. Waters that move away from the coast are replaced at the ocean surface by deeper colder water all along the coast, as far south as the southern end of Aristazabel Island.

[6] Cape St. James, south end of Moresby Island

Strong tidal currents are found at the southern tip of Moresby Island, within a few kilometres of Cape St. James and the Kerouard Islands, where speeds as high as 5 knots are found. In summer the winds from the northwest push the warm surface waters of Hecate Strait southward past Cape St. James and into the open Pacific Ocean. Tidal currents at this cape bring deep cold water to the surface where they partially mix with warmer surface water. All these water masses flow about 100 kilometres southwestward into the Pacific Ocean, forming a distinctive plume in this image.

[7] Eastern Queen Charlotte Sound

On this day the fresh water from Rivers Inlet was in a layer only a few metres thick along the eastern shores of Queen Charlotte Sound. It soaked up heat from the sun as it gradually drifted into Queen Charlotte Sound

[8] Cape Scott and Cook Bank at north end of Vancouver Island

Strong tidal currents on Cook Bank and near Cape Scott mix cold deep waters into warm surface flows. The winds from the northwest push these waters up against the shore, and they then squirt westward into the Pacific Ocean and also to the southeast along the west coast of Vancouver Island.

[9] Clouds West of Graham Island

Clouds west of Graham Island appear black, as do the jet contrails to the Northwest of Graham Island.

Water Salinity

The salinity of the in Hecate Strait and Queen Charlotte Sound, based on data from W.R. Crawford, DFO-IOS, ranges from 30 ‰ to 34‰. Figure 11 shows a depth plot of the salinity in the region. As expected, the surface waters show the greatest variability, and tend to have the lower values (30 – 32.5‰). This is due to several factors, including runoff of fresh water from land, sea surface evaporation, and downwelling.

upwelling and lateral mixing. The deeper waters are more homogeneous and converge on an ocean salinity value of 34‰.

Mapping of the isohalines (contours of equal salinity) for different depths in the region (3, 50, 100, 200 m and bottom water) are shown in Figure 8 for the summer months and Figure 9 for the winter months. Again, it is clear that the greatest variations in salinity are observed in the coastal and shallower waters.

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http://www.huskywhiterose.com/html/project_description/project/project2.html

Appendix 15: Potential Interactions Between Oil and Gas Exploration and Development and Living Marine Resources in the Queen Charlotte Basin Area[13]

ISSUE:

There is an aspiration to explore and develop the potentially valuable oil and gas resources in the Queen Charlotte Basin. The concern is that oil and gas exploration and development might adversely impact on sustainability and value of the marine fish, plants, mammals and birds, their habitat, harvests and use. This paper provides an overview of some scientific considerations of possible impacts on living resources that could result from oil and gas exploration, development and production.

AREA OF INTEREST:

The area of interest for oil and gas exploration and potential development is known as the Queen Charlotte Basin - from the north end of Vancouver Island to the border with Alaska and from exclusion zones, 20km seaward from any point of land. The highest oil and gas potential is thought to be in the Queen Charlotte Islands portion of this area.

ECOLOGICAL PYRAMID:

The following ecological pyramid represents an ecosystem in which the individual species interact. Each layer in the pyramid is dependent on the layers below it and is impacted by those above. The lower in the pyramid an impact occurs, the greater the overall impact on the ecosystem is likely to be and the more difficult it will be to demonstrate the impact on human harvest. For example, reductions in phytoplankton or zooplankton would impact most carnivores and human harvest. The recent downturn in production of many marine fish, bird and mammal species is attributed to decreased phytoplankton and zooplankton production resulting from adverse ocean conditions.

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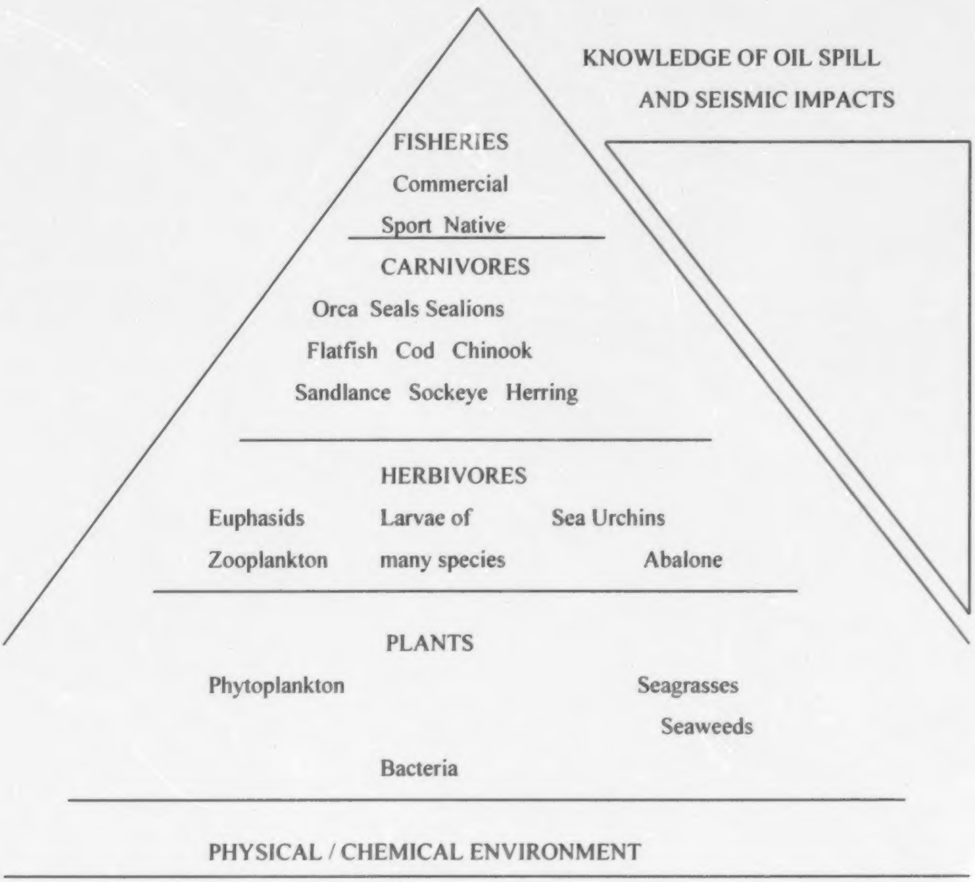
[13] Submission to Dr. Patricia Gallaugher, Member – BC Offshore Hydrocarbon Development Scientific Review Panel, prepared by Allen Wood Consulting Inc. January 7, 2002.

ECOLOGICAL PYRAMID


KNOWLEDGE OF OIL SPILL
AND SEISMIC IMPACTS
FISHERIES
Commercial
Sport Native
CARNIVORES
Orca Seals Sealions
Flatfish Cod Chinook
Sandlance Sockeye Herring
HERBIVORES
Euphasids
Zooplankton
Larvae of
many species
Sea Urchins
Abalone
PLANTS
Phytoplankton
Seagrasses
Seaweeds
Bacteria
PHYSICAL / CHEMICAL ENVIRONMENT

Most knowledge of oil and gas exploration and development impacts is related to accessible species in the intertidal area and to commercially valuable species. Although phytoplankton and planktonic herbivores directly or indirectly feed the majority of the ecosystem, there is little information on oil impacts on either. Also, most assessment has been of impacts on single species, rarely on the ecosystem. However, the impacts of ripple effects through the ecosystem are likely to be significant. A major decrease in prey species could result in a decrease in a species of interest, but because of the high natural variability of many species, cause and effect is often difficult to demonstrate.

The layers of the ecological pyramid include:

1. PHYSICAL/CHEMICAL ENVIRONMENT: Changes in the physical and chemical environment and toxic substances added to the environment by exploration, development or accidents are concerns at this level.

2. BACTERIA: "Despite their importance to ecosystem restoration, studies on role of marine bacteria in post-spill situations has been minimal." (Sloan, 1999). There is very limited work on negative impacts on bacteria.

3. PLANTS

Phytoplankton: There have been a number of studies on the effects of oil on phytoplankton using large enclosures. They found that "oil could be lethal or reduce photosynthesis and growth of phytoplankton, and, at low concentrations, stimulate phytoplankton growth." (Sloan, 1999). Impacts are dependent on the species, season, local conditions and the oil amount and type. There is limited and conflicting evidence on long-term impacts of oil on phytoplankton.

Seaweeds: Intertidal seaweeds generally are more exposed to oil deposition and residence than those in subtidal areas. As intertidal seaweeds are more accessible for observation, there is more information about impacts on them. Multicellular algae often have alternating life phases with different susceptibilities to oil, but there is little information on the gametophyte stage. Oil impacts and recovery rates differ between species, season, local conditions and the oil amount and type. Remedial cleanup actions also can have severe impact on seaweeds and on associated communities. Subtidal and low intertidal seaweeds have been observed to show increased growth due to oil death of herbivores that feed on them.

Seagrass: Portions of seagrass exposed to oil perished while subtidal portions survived. Seagrasses are killed by smothering, poisoning, and habitat destruction. Sublethal effects of oil can lower tolerance to other stresses. Tainting and loss of seagrasses affects dependent food and habitat webs.

Coastal Wetlands: Salt marsh plants are highly susceptible to chronic oil pollution, in part because oil is not washed off plants by wave action. Oil impacts these highly productive areas for a number of years (more than 6), depending on the amount and type of oil, plant species, season and local conditions.

4. HERBIVORES

Zooplankton: Oil effects on zooplankton are greatest at the water surface and in enclosed inshore areas. Zooplankton, such as euphasids, are the key food of most fish at some stage in their life. Many species contain high levels of natural oils in their eggs or over-wintering cysts as energy stores, so it is possible that they could incorporate petroleum (Reid, 1987). This oil could be transferred to their predators.

Grazing herbivores such as sea urchins, and probably abalone, limpets, chitons, and snails, are highly impacted by oil. Organisms in intertidal areas are much more affected than those in subtidal areas. Impact and recovery depends on substrate, exposure to waves, amount and type of oil, season of oiling, and species. Grazing herbivores are especially sensitive to oil and to some of the more effective oil cleanup methods.

Intertidal filter feeders such as clams, rock scallops and mussels are also impacted by oil. Clams are impacted by oil settling into sand and gravel in their habitat. Beyond mortality, there is a long-term contamination and tainting of mussels.

Eggs and larvae of many species are planktonic and feed on phytoplankton or smaller zooplankton. Many occupy surface layers so would be susceptible to oil and potentially to seismic exploration. Beyond direct mortality, larvae are especially susceptible to slow growth that leaves them exposed to predation for a longer time. Little is known about larval feeding habits and oil impacts.

5. CARNIVORES

Most species of fish feed on euphasids or other zooplankton at some stage in their lives, some throughout their lives. Examples of the latter group are herring, sockeye, pink and chum salmon. These fish can be impacted by reduced prey abundance and possibly, transfer of oil in their prey. Most are also susceptible in the egg or larval stage, and if they are in the intertidal area. Sea otters and some sea birds prey on herbivores such as sea urchins, abalone and clams. They are susceptible to oil on the water surface and intertidal area as well as in their prey. Other carnivores, such as chinook, rockfish and halibut, that eat other carnivores generally are not exposed to oil but are locally susceptible to seismic exploration and drilling. Top carnivores, such as Orcas and seals, are susceptible to variations in food supply, tainting, exposure to oil in their habitat and to the noise of seismic exploration and drilling.

Of special concern are stocks/populations that only live in a specific local habitat. For example, many salmon populations are adapted to a specific river or area. Rockfish and prawn populations stay in their local areas. Severe local impacts could result in putting such populations at risk of extinction.

Adult fishes can directly ingest oil and oiled food, take up dissolved oil compounds through their body surfaces, or their eggs and larvae can become contaminated. The highest impacts are in shallow water, near shore. The early life stages of fish are most susceptible to oil because they often are surface and/or shallow water oriented. Also, eggs and juveniles tend to be more sensitive to oil than adults. Oil dispersants tend to increase the toxic effects on young fish and eggs. Impacts range from behavioral modification and reduced predator avoidance to direct mortality.

Oil can also affect fish, such as salmon, in tidal areas of creeks. Spawning adults, eggs and larvae in the gravel, and migrating fry or smolts are all susceptible. There is conflicting information on the scale and duration of impacts in such areas.

6. HUMAN HARVEST: The human concerns are about reduced fish production, changes in fish distribution, and tainting of catch.

Fish are not evenly distributed. Some areas are relatively barren and others may be very productive and highly populated. Some areas are especially important for spawning, nursery, feeding, or adult and juvenile migration, each with different sensitivities. Consequently, some areas and times need special protection from some oil and gas exploration, development and production activities.

Impacts on fisheries include oil-contaminated harvesting gear, temporary fishing closures of oiled areas and long-term closure of fishing in oil production and pipeline areas. Fisheries for sedentary species are more vulnerable to oil and gas impacts than those for mobile species. Harvest of intertidal species is more vulnerable than subtidal species, which in turn are more vulnerable than open ocean species. Tainting of fish flesh is a concern. Although products may be declared safe to eat, tainting might still affect the taste and/or commercial and sport consumer confidence.

OIL AND GAS DEVELOPMENT

There are three phases in oil and gas development: exploration, drilling and production. Exploration is primarily by seismic surveys using air guns. Drilling would be from some type of ocean drill rig. Production would either involve a pipeline on the ocean bottom from the well to a storage site or long-term production from the drilling platform. Each of these phases has potential impacts on fish resources and fisheries. Seismic exploration impacts vary by species, time and location. In the drilling and production phases the main concern is the potential for unplanned events and accidents that could result in oil spills or deposit of debris into the ocean.

Life Stages Highly Susceptible To Oil and Gas Development

There are periods in the life cycle of marine organisms when adverse habitat conditions result in significant decreases in survival and production. The most susceptible period is the reproductive stage - egg-larval stage in fish, nesting stage in birds, birth and early life of marine mammals. Also, organisms that are resident in inter-tidal areas are especially susceptible to habitat disruption and site-specific local impacts such as physical and chemical changes in their habitat.

"Fish eggs and larvae are the life stage most sensitive to effects of oil (up to 10 times as sensitive as adults (Moore and Dwyer 1974)" cited in JWEL, 2001. In the larval life stage, growth rate is key to survival. Natural mortalities are very high in this life stage. Anything that increases mortality will impact on overall survival and ultimately on fish production. During this stage, larvae have low mobility and their location is determined by their habitat, such that they can't avoid areas of adverse conditions. Concerns include toxic materials and factors that affect marine productivity, such as by an oil spill decreasing food organisms. Physical damage to eggs and larvae from seismic exploration is also a concern. Kostyuchenko (1971; cited in JWEL, 2001) noted that mortality of fish eggs and larvae may occur within 1 to 10 metres of an operating airgun. There has been very limited research on non-lethal long-term effects on larval fish. There are similar concerns with young birds and marine mammals.

In inter-tidal areas, an oil spill could come into direct contact with adult and juvenile fish, their food and physical habitat. This is especially a concern for marine plants and the fish (primarily invertebrates) that feed on them or on detritus. It is also a concern for marine and shore birds and land animals that might feed in inter-tidal areas.

POTENTIAL IMPACTS OF CONCERN OR UNCERTAINTY RE FISH RESOURCES[14]

O & G Phase	Impacts	Generations[15] Impacted	Area [16] Impacted	Info.[17]	Available Responses[18]	Seismic
	Physical Damage					
Exploration	- mortality	1	local	some	none	
	- slow growth	1	local	?	none	
	- reproduction	1	local	?	none	
	Stress/behavior	1	local	?	none	
	Distribution	1	local	?	none	
Drilling	Cuttings/mud/toxics					
	- mortality	> 1?	local	some	yes	
	- slow growth	> 1?	local	?	yes	
	- reproduction	> 1?	local	?	yes	
	- tainting	> 1?	local	?	yes	
	Noise/behavior	> 1?	local	?	none	
	Attraction effect	> 1?	local	?	yes	
Operations	Well/shipping leakage	> 1	local	yes	yes	
	Ballast water	potential continuing problem				
	- oil	> 1	local	yes	yes	
	- other species	> 1	wide	some	yes	
	Pipeline	> 1	local	some	yes	
Accidents	Blowouts/spills	short, medium and long-term impacts				
	- mortality	> 1?	wide	yes	maybe?	
	- slow growth	> 1?	wide	some	maybe?	
	- reduced reproduction	> 1?	wide	some	none	
	- tainting	> 1?	wide	some	none	
	Debris on sea bed	< 1?	local	yes	yes	

Seismic Exploration

There are concerns about physical damage to fish by seismic exploration. It is expected that new seismic techniques would localize and minimize impacts much more than the earlier seismic exploration on the BC coast that resulted in considerable fish kills. In the past, adult fish floating on the surface were visible signs of damage. There is also concern about much less visible damage that might occur to fragile eggs, larvae, juveniles, and species that don't float to the surface. Any distributional changes resulting from seismic exploration could have a short-term affect on both the fisheries and their management.

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[14] Recognizing that many impacts are situation specific and often unpredictable.

[15] Number of generations of fish impacted

[16] Size of area impacted; local is immediate area only

[17] Amount of information available on the topic

[18] Are there proven remedial actions to address\minimize the risk and impacts?

If seismic exploration were limited to from June to October, it would coincide with the migration of juvenile salmon and the larval stage of many shellfish species, herring, and a number of other forage fish. The available research suggests that the seismic impacts are relatively local [definite mortality within 6 meters of an air gun for fish and up to 10 metres for eggs and larvae]. There is little information on non-lethal damage at greater distances from the air gun. A 3-D seismic survey would have grid lines as close as 100 meters apart (JWEL, 2001). This would mean that up to a 20% incremental mortality could be expected in surface oriented larvae in the survey area [10 meters of mortality to the left and right in every 100 meters]. There could also be damage and mortality to adult fish in close proximity to the air gun - 12% mortality of the fish in the surface layer. However, it is expected that most adult fish would avoid the area of the seismic work. Juvenile and non-migrant species could still be impacted. For example, inshore rockfish would likely not leave their home territory unless forced to. Using higher frequencies, high resolution seismic profiling could impact a broader size range of fish than regular seismic profiling.

A Norwegian study (Engas et al, 1993. cited in JWEL, 2001) found that seismic shooting affects fish distributions for 18 to 20 nautical miles (33 to 37km) on either side of the shooting area, and resulted in reduction in trawl catches by 70% in the shooting area and by 50% over the entire study area. This displacement lasted for at least 5 days. Based on published reports it is assumed that marine mammals would also avoid seismic shooting areas if given an early warning.

Table 5.1, on page 79 in the JWEL report lists maximum noise levels of Seismic Exploration Devices at 212-230 dB. However, Table 6.2, on page 112, only lists effects on fish and whales at lower than maximum air gun sound levels (e.g. 168dB elicited an alarm response from rockfish). As the decibel scale is logarithmic these differences could be significant.

If seismic shooting affects fish distributions for up to 37 km on either side, many fish within a 20km exclusion zone could be affected. Of particular concern would be the resident rockfish populations in areas such as outside of Banks and Aristazabal Islands that would be in the outer portion of the exclusion zone. Depending on the timing of the seismic work, the nursery areas on the east coast of the Queen Charlotte Islands and in many other areas, could also be special concerns.

Drilling Oil And Gas Wells

Potential impacts on fish of drilling oil and gas wells could result from disposal of drill cuttings, drill mud and toxic materials. This could affect bottom dwelling species and bottom fisheries. These impacts would likely be highest in low current areas where these materials would stay near the well. In high current areas, these wastes would tend to be spread over a considerable area, moderating their effects. There are a number of approaches for disposal of drill cuttings and discharges that reduce the risk to the natural environment. 'Produced water' has local risk of toxic components to sessile organisms and sub-lethal effects to larvae and to older invertebrates. In high current areas, mixing would moderate this effect. Based on experience in other areas, the input materials could be controlled and outputs managed to moderate impacts on organisms in the local area.

There is some concern about local impacts of drilling. All finfish have a lateral line for sensing low frequency sounds and pressure changes and ears for balance and higher frequency hearing. Consequently, it should be expected that finfish might react to drilling sounds, probably being repelled by them. Sounds are stressing for some animals and some frequencies and volumes of sound may also disrupt their normal uses of sound. [For example, Orcas use sound for echolocation and finding food, and chinook salmon react to Orca sounds to avoid capture.] The volume of sound from drilling is loud enough (up to 185 dB, Table 5.1 JWEL, 2001) to cause severe stress in the immediate area of the sound source (Table 6.2 JWEL, 2001).

Oil and gas development can also impact fisheries by drill rigs, wells and pipelines occupying fishing areas (especially key trawling areas) and by disposal of drill cuttings in bottom trawling areas.

Oil and Gas Operations

Platforms, their anchors, and pipelines require a buffer zone around them to prevent damage and potential oil leakage. The Atlantic Canada protection zones are 500 meters from the drilling rig or production platform, 50 meters from its anchors and 200 meters from submarine pipelines. Clearly, such protection zones are required. From 1974-1995, 88.9% (67,710 barrels) of spills larger than 1,000 barrels, in the US

Outer Continental Shelf were attributed to trawl or anchor damage. The size of this protection zone for a pipeline could cause a significant reduction in fishing area, depending on the location relative to centers of fishable populations and length of pipeline. In a positive sense, these protection zones could serve as no-fishing, marine protected areas.

Operational platforms in other locations provide a reef habitat that attracts fish and apparently outweighs any negative impacts of operational noise or other habitat impacts. In some locations there has been a significant stimulation of local production. Presumably, that reef effect could be enhanced by platform design and possibly by induced upwelling in the area.

There are biological concerns related to release of oil with oil tanker ballast water, storage tank displacement water, and from other sources. Introduction of exotic species in oil tanker ballast water is also of concern. Both of these concerns can be addressed by good practices.

ACCIDENTS - OIL SPILLS

Oil pollution is the biggest long-term concern related to oil and gas exploration and development. There are numerous potential oil sources that are of environmental concern, ranging from oil in displacement water in storage tanks to oil spills, leakage, blowouts, pipeline damage, and tanker and storage problems. Oil spills could affect all species resident, reproducing, or feeding in intertidal areas and salt marshes. This would include salmon, herring, abalone, sea urchins, sea cucumbers, clams, and sea and land birds and some marine mammals. Spills could also affect all plants and animals in the surface and upper layer of the ocean, including most larval fish and planktonic eggs, and marine birds and mammals.

The incidence and extent of oil spills seems to differ a lot between jurisdictions. For example, JWEL (page 95) reports that for spills related to pipeline operations in the US Outer Continental Shelf, between 1964 and 1984, there were 34,874 spills of 50 barrels or more of oil spilled per billion barrels handled. If the 34,874 spills averaged 50 barrels, the total oil spilled would have been 1,743,700 barrels or about 0.17% of production. However, the spills are "50 or more barrels", including oil spills of 50 to 999, more than 1,000, more than 10,000, and more than 150,000 barrels. If the average spill size was 525 barrels (half way between 50 and 999) it would have been 18.3 million barrels or more than 1.8% spilled. If the spills over 50 barrels averaged 1,000 barrels it would have been 34.9 million barrels, or about 3.5% spilled. In any case, this declined to 9,122 spills (0.046% to 0.9% of production) from 1985 to 2000. On page 93 of JWEL, 2001, reports another apparent source of oil spills that would double the amount spilled. For offshore platform operations, there were 34,047 spills of 50 barrels or more reported between 1964 and 1984. Between 1985 and 2000 this had dropped to 821.

In contrast, Canadian offshore spills reported in JWEL, 2001, ranged between 0.00052% and 0.00008% of oil production between 1997-8 and 2000-1. This suggests that Canada has a lot less oil spilled than the US. This may be related to misinterpretation of US numbers, more stringent Canadian requirements, shorter-term Canadian operations with newer equipment, or how Canadian spills are reported. Canadian regulations largely rely on voluntary reporting of the occurrence and size of spills (www.offshore-environment.com/drillingwastecontents.html).

LIVING MARINE RESOURCES IN QUEEN CHARLOTTE BASIN

The specific concerns related to impacts of oil and gas exploration and development are discussed for each basic group of marine plants and animals. Also, high-risk times and areas are identified, as for example, for seismic exploration or susceptibility to oil spills.

SALMON:

There are six species, many stocks and more than 5,000 populations of salmon that spawn in streams adjacent to Queen Charlotte (QC) Basin. There are many more that rear in or migrate through the Basin as juveniles and returning adults. In total, almost all BC salmon pass through the Basin, except for a small portion of some southern coho stocks and Stikine and Taku River stocks.

Chinook and coho salmon tend to rear in coastal areas for most of their marine life. They also tend to migrate north such that many coho from southern BC and chinook from southern BC, Washington and Oregon also rear in and migrate through the area.

Chum, pink, sockeye and steelhead all rear in coastal areas for a short time before moving to open ocean areas where they rear to maturity. They then migrate back to their home stream to spawn, again passing through the QC Basin.

Most spawning takes place from September to November. Most juveniles enter the Basin in the spring (May-June). Chinook and coho may be present in the area in all months of the year. Most returning adults pass through the area from June to October.

There are very important commercial, recreational and Native salmon fisheries in the QC Basin. All salmon fisheries, except commercial troll, take place inside a 20km exclusion zone so would not be directly impacted by exploration or production, except by accidental oil spills or displacement of fish by seismic exploration.

Data Sources: Spawner counts for salmon populations in the streams tributary to the QC Basin are available at www.pac.dfo-mpo.gc.ca/ops/northernfm/Areas/default.htm. Adult stock timing, migration rate and route information is available from DFO. Catch information from 1880s to the present is available. The early data is for broad areas and the more recent is by small local areas and times. Stock assessment reports are available at www-sci-pac.dfo-mpo.gc.ca/english/psarc/default.htm. There is extensive information on salmon biology in freshwater. However, in the estuary, coastal and ocean areas there is very limited information on juvenile migration routes, rates, timing, survival and growth, especially in this area.

Potential Oil and Gas Exploration and Development Concerns - Salmon

Oil & Gas	Egg	Larva	Juvenile		Adult	Fishery	Products
			Estuary	Coastal			
Seismic				× ?	?	× ?	
Noise	×	×	×	× ?		?	?
Oil Spills						×	

? = unknown; × = known negative impacts; × ? = uncertain but likely impacts

If seismic exploration is limited to favorable weather conditions it would coincide with juvenile and adult migrations. Adult salmon are expected to be minimally affected by seismic exploration. Small juvenile salmon may not be able to move away from the shock and noise of seismic exploration.

Much of the Outer Coastal area on the east side of the Basin is low elevation. For example, on Aristazabal Island there are 16 streams with 60 salmon populations. Streams in such areas tend to be short with much of the spawning area in or near the intertidal area. These areas could be subject to oil spills, as occurred in the Exxon Valdes spill in Alaska.

Throughout the area, the estuaries and shallow areas where juvenile salmon rear, could also be affected by oil spills.

Seismic exploration and drilling might cause enough noise to displace adult salmon.

HERRING

There is one herring species and five stocks that are associated with the QC Basin. The QC Islands, North Coast and Upper Central Coast (Milbanke-Queens Sounds) stocks are large. The Lower Central Coast (Area 8-10) and Johnstone Strait (Area 11-12) stocks are small and erratic. Herring spawn in March-April in sub-tidal and inter-tidal areas, usually on marine plants. They incubate for about 3 weeks before hatching into planktonic larvae. Juvenile herring feed in the coastal areas before migrating out into the Basin and the outer coast.

Hose et al (1996) reported sub-lethal lesions and morphological and cytogenic abnormalities and other sub-lethal effects on herring exposed to oil. Brown et al. (1996) suggested that affected herring were more susceptible to parasites because of their low physiological condition, but that specific causes can't be demonstrated because of poor understanding of natural recruitment. "Although much of the population level effects on herring remain speculative, the prospect of long-term sub-lethal effects on young herring cannot be discounted despite great uncertainties with the region's herring natural history." (Sloan, 1999).

The herring populations in the QC Basin support both roe and spawn-on-kelp fisheries. They also support important Native fisheries. All herring fisheries would be in the 20km exclusion zone, but could be subject to oil spills.

Data Sources: There is considerable information on individual herring populations, their biology, local spawn deposition, survival of year classes and harvests. This information is available from DFO.

Potential Oil and Gas Exploration and Development Concerns - Herring

Oil & Gas	Egg	Larva	Juvenile Coastal	Adult	Fishery	Products
Seismic		?		?		
Oil Spills	×	× ?	× ?		×	×

? = unknown; × = known negative impacts; × ? = uncertain but likely impacts

Herring larvae might be impacted by seismic exploration, in the immediate area of an air gun.

Herring spawn in inter-tidal areas could be highly impacted by even minor oil spills. Even a thin film of oil would likely affect the oxygen exchange capabilities and other physiological processes of the eggs.

The spawn-on-kelp fishery would also be highly susceptible to oil spills. Even small amounts of oil would taint the product. There is also a question of petroleum oil tainting of the natural oils in herring roe and flesh.

Other Forage Fish

Important forage fish, have received much less study than herring, in general, and specifically with regard to oil and gas exploration and development impacts. There has been considerable work done on the effects of oil on herring, but very little done on sand lance and oolichan.

The sand lance is a small fish that lives in shallow water where it could be subject to oil spill impacts. In the Queen Charlotte Basin, sand lance is a preferred food for rock sole, petrale sole, pacific cod, chinook, coho, lingcod, halibut, and many other fish species and some seabirds. Sand lance larvae are likely of major importance to pelagic food webs. Sand lance feed on plankton, especially small crustaceans that could also be subject to oil spill impacts. As sand lance spawn in the spring, larvae could be subject to damage by seismic exploration.

Oolichans are small, smelt-like fish with great cultural and subsistence importance to First Nations. They spawn in the estuary or low reaches of large rivers. Eggs attach to the river bottom. Larvae are washed downstream to the marine environment as free floating planktonic larvae. As they grow, they migrate out into the QC Basin where they rear for 2+ years. The juvenile oolichan are slow swimmers and somewhat fragile. The impact of seismic exploration on larvae or ocean juveniles is not known. Most life stages could be impacted by oil spills, and tainting is an important concern.

Anchovy and sardine populations are centered off California but can be important forage fish in waters off BC. They feed on plankton in the upper layers of the ocean. Presumably there is experience with oil effects on these species in California and possibly other areas.

GROUNDFISH

There are more than 70 species of groundfish in the QC Basin. This includes general groups such as rockfish, flat fish, and pelagics.

Most groundfish have planktonic larvae that usually occupy the upper 25 meters of the water column. Spawning usually takes place in the fall, winter or early spring. The larval stage is usually about 4 to 6 weeks. If seismic exploration were limited to June to October, few larvae would be subject to seismic damage.

Data Sources: For approximately 50 groundfish species, there is extensive information on fishing areas and catch by specific map square location. For example, see Fargo et al 1990, Figures 5-18, and Fargo et al

1991. There is information on spawning and nursery areas, times of spawning, and time and distribution as larvae. For example, Reef Island, off Selwyn Inlet, is an important nursery area for rock sole, the west side of Graham Island to depths of 30 m is a nursery area for at least 5 species of flatfish, and Browning Entrance is a spawning area for Pacific Cod. There is also information on seasonal and age class geographic distribution, as for example, lemon sole that occupy the inshore shallows along the east coast of Graham Island in their first year, then move into deeper water in the area in subsequent years (Ketchen, 1956, Figure 11). Also, dogfish populations move into the shallow water on the west side of Hecate Strait during the summer to feed on invertebrates, juvenile sole and other species.

This groundfish information is available in two databases at the Pacific Biological Station (PBS), one on catch and the other on biology. The catch database includes information from the early 1950s to the present. The early information is by general fishing grounds. From 1991 on the information is by individual tow and data from 1996 on is from 100% observer coverage with GPS locations. The ZN rockfish longline fishery also now has 5% observer coverage. Stock status reports for some species are available at www.pac.dfo-mpo.gc.ca/sci/psarc/SSRs/groundfish-ssrs.htm.

A model of the groundfish population assemblages in the Hecate Strait area is being constructed. This will allow exploring the dynamics of the stocks in the area and better understanding of the observed changes in populations related to habitat factors. At some future time, this model could be extended to cover Dixon Entrance, Queen Charlotte Sound and Strait and the West Coast of the Queen Charlotte Islands[19]. Such a model could help to understand the baseline situation and to explore the implications of oil and gas exploration and development in various areas of the QC Basin.

There is limited specific information on the bottom habitat in the Queen Charlotte Basin. Whenever possible, this information is being acquired opportunistically. If oil and gas exploration goes ahead, it could provide an opportunity to get detailed habitat information to go with catch and other fish information to increase the strength of the model for the area. This could be an opportunity for cooperative work.

These databases and model(s) could be available for use for oil and gas exploratory work and assessment. PBS might be contracted to do some work. There is strong staff capability and knowledge but very limited operational money to conduct fieldwork.

The most abundant and commercially important groundfish are as follows:

Flatfish are bottom fish, most of which are associated with relatively flat seabed areas. Important flatfish species in the QC Basin include:

Rock Sole[20]: there are 4 discrete populations (2 QC Sound, 2 Hecate Strait (N,S)) of this shallow water flatfish that is most abundant in northern Hecate Strait. It is harvested in a directed trawl fishery and as bycatch in the Pacific cod fishery.

English Sole[21] and Dover Sole[22]: these Hecate Strait stocks are two of the four most important flatfish stocks in BC. English Sole are mainly in northern Hecate Strait.

Halibut[23]: in the QC Basin are part of a stock that occupies a broad area along the west coast of North America.

Butter Sole[24]: stock is centered in Skidegate Inlet

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[19] Note: as there is only about 12 to 15% trawlable water on the west coast of the QCI, there is limited information on the fish there.

[20] Rock Sole: Lepidsetta bileata, Lepidsetta petroborealis

[21] English sole: Parophrys vetulus (also called Lemon sole)

[22] Dover sole: Microstomus pacificus

[23] Halibut: Hippoglossus stenolepis

Turbot: is a significant Hecate Strait stock

Rockfish occupy mid-water areas with slope, shelf and near-shore species, most of which are associated with rocky, sloped bottom terrain. Some live-bearing species have internal incubation and no free larval stage. Rockfish are often very long-lived (40 plus years) and take a long time to maturity, consequently a long time to rebuild populations from any damage.

Important rockfish in the QC Basin include:

Pacific Ocean Perch[25]: stocks in Hecate Strait and Queen Charlotte Sound are the most important rockfish taken in BC waters. They live at depths of 40 to 640 meters over a cobble or rocky high relief substrate. They have internal fertilization, with the young extruded in March off Vancouver Island, later in QC Sound. Juveniles remain pelagic until their 2nd or 3rd year

Orange rockfish[26] occupy slope, shelf and inshore areas of Hecate Strait and QC Sound

Silvergray[27] and yellowtail[28] rockfish are in abundance in QC Sound

"Inshore rockfish" such as: yelloweye[29], quillback[30], copper[31], china[32], black[33], and tiger[34] rockfish, are found in rocky reef habitat as is found off of Banks and Aristazabal Islands and many other areas in the QC Basin.

There are important commercial, sport and Native fisheries for rockfish in the QC Basin.

Pelagics are mid-water species. They have swim bladders so could be subject to damage by seismic exploration. Their eggs hatch into larvae that occupy the surface waters where they could be subject to both seismic exploration and oil spills.

The pelagics include:

Pacific Cod[35]: one of the most important groundfish in the BC trawl fishery. There are major stocks in Hecate Strait and Queen Charlotte Sound. Spawning in February – March

Sablefish/Blackcod[36]: an especially high value species. There are two stocks (N, S) in BC. They spawn from January to March and are larvae from April – May. Juveniles rear in nearshore and shelf areas until age 2-5. Adults inhabit the shelf and slope water to depths of 1500 metres.

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[24] Butter sole: Isopsetta isolepsis

[25] Pacific Ocean Perch: Sebastes alutus

[26] Orange rockfish: Sebastes pinniger

[27] Sivergray rockfish: Sebastes brevispinus

[28] Yellowtail rockfish: Sebastes flavidus

[29] Yelloweye rockfish: Sebastes ruberrimus

[30] Quillback rockfish: Sebastes maliger

[31] Copper rockfish: Sebastes caurinus

[32] China rockfish: Sebastes nebulosus

[33] Black rockfish: Sebastes melanops

[34] Tiger rockfish: Sebastes nigrocinctus

[35] Pacific cod: Gadus macrocephalus

Pollock[37]: are important in Hecate Strait

There are valuable commercial trawl, long-line or trap fisheries for these species in the QC Basin.

Potential Oil and Gas Exploration and Development Concerns - Groundfish

Oil & Gas	Egg	Larva	Juvenile	Adult	Fishery	Products
Seismic			× ?	× ?	× ?	
Drill Mud			?	?	?	?
Platform				?	+ ?	
Noise	× ?	× ?	?	?	?	
Pipe. Const.			× ?		?	
Pipe. Ops.					× ?	
Oil Spills					?	

? = unknown; × ? = uncertain but likely impacts; + ? = possible positive impacts;

Noise of seismic and drilling could displace fish

Bottom feeding species might be impacted by drill cuttings and drill mud

Pelagic eggs and larvae, and juveniles in shallows, could be susceptible to an oil spill

Oil could affect forage/prey species

Some species could benefit from the reef effect of offshore platforms

There is a general lack of knowledge of long-term impacts of oil and gas activities or accidents on the fish

Fisheries could be displaced by changes in fish abundance and distribution, and by protection zones around platforms and pipelines

SHELLFISH / INVERTEBRATES:

There is a wide array of shellfish species in the QC Basin, including: clams, octopus, squid, abalone, shrimp, prawns, crabs, sea urchins and sea cucumbers. Most shellfish have planktonic larvae that usually occupy the upper part of the water column. The larval stage for most species is in the spring-summer, when they would be susceptible to seismic work. Many shellfish species occupy intertidal and subtidal areas where they would be highly susceptible to oil spills.

Data Sources: There is a considerable amount of information on all shellfish species caught commercially. This catch by time and area information is generally available unless limited by the Privacy Act[38]. Harvest log data is available on commercially exploited species such as shrimp, crab, prawn, octopus, geoducks, red and green sea urchins, and sea cucumbers. Information includes date, sub-area and location, depth, time, species, number and weight caught, and time fished. Some data is geo-referenced for: geoducks since late 1970; sea cucumbers since 1984; red sea urchin since mid-1980s; green sea urchin since 1987; shrimp by trawl since 1997; crab and octopus since 2000; and shrimp by traps since 2001.

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[36] Sablefish: Anoplopoma fimbria

[37] Walleye Pollock or whiting: Theragra chalcogrammus

[38] For times and areas where there were 3 or fewer vessels reporting, catch would be consolidated with data from an adjacent time or area.

"Fishery Updates", available on the DFO website, report effort, landings and landed value of each fishery, and a biological synopsis, management objectives and issues, and stock assessment activities. This information helps to explain management impacts such as closures, area rotation, and protected areas.

Biological information (not related to fisheries) is available for intertidal clams, shrimp, abalone and sea cucumbers. Most survey data (published and unpublished) is in databases at PBS. Also, there is extensive staff knowledge of shellfish and experience with assessing stocks and their habitat. These and other assets would be an essential input to establishing baseline information, researching likely impacts, and doing follow-up assessments of oil and gas development. Parks Canada also has considerable resource inventory data and reports on Gwaii Haanas and other areas. LUCO has an array of resource inventory data and maps related to shellfish.

Mollusks: most are in coastal areas, are resident or don't migrate significant distances. Clams, including geoducks, occupy sand/gravel bottom areas and are filter feeders. Clams live in both the intertidal and sub-tidal areas. Abalone live on rocks in sub and inter- tidal areas, feeding on marine plants growing there. Abalone abundance is so low as to be endangered in the QC Basin. Most mollusks have pelagic eggs and larvae that may be transported by ocean currents before settling to the bottom to start their adult life.

Important mollusk species in the QC Basin include:

Native Littleneck[39] clams: occupy the mid to lower intertidal zone. They spawn from April to October and larvae are planktonic for 3 to 4 weeks.

Geoduck[40] clams: occupy sand, silt, and soft gravel areas from intertidal to 110 metres. They spawn in June-July and larvae are planktonic for 40 to 50 days. Geoducks can live to 100+ years of age.

Butter and razor clams, mussels, scallops, octopus and squid are also present in the area and are locally important.

Crustaceans, such as shrimp, prawns and crabs, live from intertidal to deep water, areas in diverse habitats throughout the QC Basin.

Important crustaceans in the QC Basin include:

Shrimp[41]: 7 species, including prawns; spawn in late fall to early winter. Females carry the eggs until they hatch. Larvae migrate diurnally moving towards the surface at night. They spend about 3 months in the water column before settling to the bottom. Habitat varies between species including rocky to mud/sand bottom to upward in the water column. They occupy coastal areas of North Coast inlets and offshore areas of the Central Coast. There are both commercial and recreational fisheries on shrimp and prawns.

Crabs: live in sandy bottom areas that are less than 50 metres depth and that are subject to moderate currents. Dungeness, red rock, red king, graceful, and golden king crabs are all harvested in the area. They are opportunistic feeders. In the fall, eggs are laid and carried externally by the female. In the spring, the eggs hatch into planktonic larvae that develop for 3 to 4 months before they settle to the bottom. They occupy areas from intertidal to 50 metres depth. There are populations of dungeness crabs[42] in Dixon Entrance (Naden Harbour, Virago Sound, McIntyre Bay), and in Hecate Strait, and the Skeena River Estuary.

Crustaceans grow by molting their shell and growing a new, larger one. During molting and the subsequent soft-shell stage, crustaceans are highly susceptible to oil pollution, as well as physical damage. Oiling has been shown to be acutely toxic to crabs (Rice et al 1977). Oiling can cause narcotization and impaired movement in crustaceans (Johnson 1977). Sub lethal effects of oil have been documented (Johnson, 1977).

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[39] Native Little Neck Clam: Protothaca staminea

[40] Geoduck: Panopea abrupta

[41] Shrimp: Pandalus sp

[42] Dungeness Crab: Cancer magister

but not long-term effects. The fine sand-silt ocean areas preferred by crabs tend to trap and hold oil. Pearson et al 1980 indicates that adult Dungeness crabs can detect and avoid contaminated areas. However, crab larvae don't avoid oil and oil impacts on the larvae are not known.

Urchins and Cucumbers

Sea Urchins: 5 species in BC. Red[43], green[44] and purple are commercially harvested. Urchins live on a rocky substrate in shallow water (intertidal to 50 to 125 [140+] meters) with moderate to strong currents. They live in sub and intertidal areas, feeding on marine plants. They have planktonic eggs and larvae. Sea urchins are highly sensitive to oil.

Sea Cucumbers[45]: 30 species in BC, inter-tidal to 250 metres in a wide variety of substrate and current conditions; mainly moderate current on cobbles, boulders, crevassed bed rock. Sea cucumbers eat organic detritus. They spawn in spring to early summer with planktonic larvae for 2 to 4 months. Fishery is by divers in coastal areas and is about 3 weeks in the fall-winter.

Potential Oil and Gas Exploration and Development Concerns - Shellfish

Oil & Gas	Egg	Larva	Juvenile	Adult	Fishery	Products
Seismic	?	?	?	× ?	?	
Drill Mud			?	?	?	?
Platform				?	?	
Noise	× ?	× ?	× ?	?	?	× ?
Pipeline				× ?	?	
Oil Spills					× ?	

? = unknown; × ? = uncertain but likely impacts

Seismic exploration could impact eggs and larvae in surface areas

Species occupying inter-tidal areas and feeding on marine plants could be impacted by oil spills

Seismic and drilling noise could affect distribution of mobile shellfish

For drilling taking place in rearing and harvesting areas for shrimp, prawn, crabs, geoduck, drill mud could affect the habitat, and possibly shellfish products, unless it is carefully managed.

Many of the invertebrate species in the area have never been assessed for their sensitivity to exposure to oil, singly or their ecosystem.

Pipeline construction could displace some shellfish and have a short-term habitat impact. Pipelines would displace fisheries in the immediate area.

Oil spills are the biggest concern, likely impacting some life stage of most shellfish, some long-term. Most oil spill impacts will be in intertidal areas. However, the impacts of oil on larvae in surface layers are unassessed.

OTHER SPECIES

There are a number of species of ecological, economic, and social importance that are not included in these broad categories, including: marine plants, sponges, marine mammals and marine birds.

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[43] Red Sea Urchin: Strongylocentratus franciscanus

[44] Green Sea Urchin: Strongylocentrotus droebachiensis

[45] Cucumber (giant red?): parastichopus californicus

Marine Plants: There are diverse and extensive marine plants in the Basin. Those plants that are intertidal or float at or near the surface of the ocean would be affected by oil spills. Other plants would be less affected. Damage to plants would severely impact the ecosystem. Loss of marine plants removes both food and cover for many organisms, especially larvae and juvenile fish. Also, a kelp[46] is a key component in herring spawn-on-kelp.

Data Sources: LUCO has assembled a database on distribution of marine plants such as eelgrass and kelp beds. There is limited information the distribution of most other species of marine plants. Some biological information is available on some species. There is considerable traditional knowledge on local distribution of marine plants used for food or herbal remedies.

Marine sponges: There is a large "forest" of cloud sponge in the Hecate Strait area. It is a unique population. This type of glass sponge is thought to live for periods in the order of centuries. Actions are being taken to seek marine protected area status for the site. It could be highly impacted by drilling, drill cuttings, drill mud, platform anchoring, and pipeline construction.

Data Sources: The distribution and structure of these sponge forests is documented on videotape. There may also be information from trawl logbooks.

Marine mammals commonly encountered in the Basin include whales, porpoises, dolphins, seals, sea lions, otter and mink. Land mammals, such as bears, also commonly visit intertidal areas. Marine mammals show no avoidance of oiled areas and will always be at risk in a spill. Oil spills have relatively low impact on whales, dolphins, porpoises, seals, sea lions, but high impact on sea otters, and probably river otters and mink, because they lack an insulting fat layer. Seals do not avoid oil and continue to use oiled haulouts, including for birth and nursing of pups, and for summer molting. Impacts on seals include increased pup mortality and oil ingestion while nursing, and eye and brain damage. In Alaskan, after an oil spill, declines in killer whale population were observed, but observations of abundance of other whales were inconclusive. Whales and dolphins would likely be most affected by sounds of seismic exploration and drilling. Concerns have been expressed about the possibility of reduced hearing and partial deafness.

Data Sources: There are considerable amounts of information at PBS, on the abundance, distribution and biology of common marine mammals. The Vancouver Aquarium has extensive information on biology of marine mammals. LUCO maintains a database on haulout areas.

Marine Birds are an important resource in the QC Basin. Millions of birds live, breed, and migrate through the area including: albatrosses, alcids, auklets, black turnstones, cormorants, crows, eagles, fulmars, ducks, geese, great blue herons, grebes, gulls, kingfishers, loons, mergansers, murrelets, oystercatchers, phalaropes, peregrine falcons, puffins, shearwaters, storm petrels, swans, and many others. All could be adversely impacted by oil spills, leakage and low-level pollution. Birds feed at all levels of the food chain, eating vegetation, zooplankton, shellfish and fish. Many feed in intertidal areas so food supply could also be affected. Affects include mortality, reduced reproduction, growth and distribution. The worst impact is nesting failure.

Birds nest in many areas along the coast. For example:

Cassin's Auklets nest on Triangle Island, along the east coast of Moresby Island, particularly on Kerouard and Anthony Islands, and on the west coast of Graham Island.

Rhinoceros Auklets nest on Triangle Island, on Storm and Pine Islands, and in Chatham Sound, particularly on Lucy Island.

Tufted Puffin nest on Triangle Island.

Storm Petrels nest at a number of sites along the east coast of Moresby Island, particularly in Engfield Bay, on the west coast of Graham Island, on Tree Island, and on the Buckle Group.

Ancient Murrelets nest at a number of sites along the east coast of Moresby Island, particularly on Lyell Island, on the west coast of Graham Island, and on Byer's Island.

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[46] Kelp: Macrocystis integrifolia

Marbled Murrelets nest in trees along much of the coast.

Seismic exploration would likely impact bird distribution and nesting. For example, "Cassin's Auklets are very sensitive to disturbances during the nesting period. Adults will readily desert their nests if disturbed during the incubation or brooding period." (Booth, 1999) The natural variability of bird distribution and abundance, and incomplete baseline information make it difficult to demonstrate oil impacts unless they are extreme. An accurate census of populations of even the major colonies is incomplete, especially for populations on the east coast of the Basin. Scientific information on important issues, such as offshore birds' feeding ecology, is lacking.

Data Sources: The Canadian Wildlife Service maintains databases on bird populations and distribution. LUCO also has a database on major nesting areas.

SENSITIVE AREAS AND TIMES

The many sensitivities of organisms in the QC Basin determine how big an impact oil and gas exploration and development could have on the ecosystem and on fisheries and other dependant industries there.

At some time of the year many marine and shore areas could be rated as sensitive because: they are breeding or nursery areas; fish larvae or juveniles, or young birds or mammals are present; they are important feeding areas for birds, mammals or fish; resident, non-migrating fish are present; or it is a fishing area. Breeding and nursery areas are seasonal and differ for each species. For example, rock sole spawn near Reef Island (Mouth of Selwyn Inlet) in the fall; lemon sole spawn along the northeast coast of the Charlottes; pacific cod spawn in Browning Entrance in winter, at least five species of flatfish spawn along the entire west side of Hecate Strait off Graham Island (to 30m); herring spawn in late winter on marine plants over much of the area; dungeness crabs carry their eggs through the winter to spring in Naden Harbour and McIntyre Bay; in summer, clams spawn throughout the area; and salmon spawn in fall, in streams throughout the area. Birds nesting and marine mammal birthing generally takes place in the spring or early summer in many areas around the Basin.

Many species can't avoid high-risk areas. The planktonic eggs and larvae of many species may be carried over extensive areas by currents, wind and tides. Consequently, eggs and larval fish can't avoid high-risk areas, such as those undergoing seismic survey or an oil spill. Similarly, small juvenile fish can do little to avoid such problems so are at risk to them. Nesting birds and seals and sea lions are tied to their nursery areas. All species are at least somewhat tied to their usual feeding areas. Resident fish are tied to a location either by immobility, such as marine plants, clams and mussels, or by low mobility, such as crabs, sea urchins and shrimp. Behavior also ties some resident fish, such as some rockfish species and prawns, to their local area. Such resident species are at risk to seismic exploration and to oil spills in intertidal areas.

Distribution of many fish, birds and marine mammals varies seasonally and by age. For example, in their first year lemon sole occupy shallow areas near the northeast shore of the Queen Charlotte Islands. As two year olds they move into deeper water. As three year olds they occupy even deeper areas (Ketchen, 1956). Dogfish move into shallow areas on the west side of Hecate Strait during the summer to feed. During the spring and summer juvenile salmon migrate through the area heading to ocean rearing areas. In the summer and fall adult salmon migrate through the area heading to their home streams to spawn. In response to the fish, the fisheries also change by season and between years, as illustrated in Fargo et al 1990. Migrant birds and marine mammals pass through the area in the spring and fall and many over-winter in the area. For example, shearwaters are present from about April to November. Geese, swans and ducks pass through the area in November and April. Young fur seals over-winter in the Basin.

INFORMATION NEEDS

The fisheries ecosystem in the Queen Charlotte Basin is complex and dynamic. There is considerable information on some parts of the ecosystem. However, most of the information has only recently started to be integrated into an interrelated system so that interactions and interdependencies can be explored. Much of the new data is now geo-referenced and much more area specific than earlier data. Also, as much data collection is now by onboard observers rather than fishing crew, the data are more accurate. There is now considerable information on marine fish, birds and mammals and their ecosystems, on physical and chemical environments and ocean dynamics, as well as on fisheries. Some of the new information is being collected by new sensors in digital format that can be transmitted in real time by satellite for real time analysis. There are many new technologies for sampling, analysis and presentation of information. New computer modeling for fish assemblages and their ecosystem allows better understanding of how the parts interact. Models bring together the diverse data to better understand impacts, interactions and interdependencies.

There is considerable information on things such as catch, but very little on many other things. Key weaknesses in our understanding of the biology of oil impacts remain:

> Very few of the species in BC waters would be rated as "well studied". For example, only about 10 of 60 to 70 groundfish species are being adequately assessed. Most species of marine fish, birds, plants and mammals have not been adequately assessed to provide a baseline for predicting and measuring impacts of possible oil spill impacts.
>
> There is an inability to differentiate natural ecosystem changes from oil pollution effects. Natural fluctuations in fish and bird recruitment are so great that even in well-studied species, oil-induced mortalities of juvenile and pre-recruit fish would have to be very large to be detectable. The same applies for many marine birds. Longer-term impacts would be even more difficult to prove.
>
> The greatest information shortfall is for those impacted species: that are not easily accessible, such as those not in intertidal areas; those that don't float to the surface during seismic exploration; or those that are not recovered on the shore after an oil spill.
>
> There is a general lack of information on impacts on species in the lower levels of the ecological pyramid that those in the upper layers of the pyramid are dependent on.
>
> Most impact studies have been of individual species rather than of multi-species ecosystems.
>
> Various agencies and groups have assembled a lot of information, but much of it is not currently interconnected. It should be brought together so that it can be interrelated, ideally in a computer model(s). This would facilitate identification of known sensitive times and areas; likely interaction impacts, important data gaps, and could facilitate agencies working together.
>
> There are many initiatives to structure, collect, store and analyze data and make it accessible. However, initiatives, such as the oil spill atlas for the area, are not yet complete and at least some are incompatible with others – some pieces are missing and others don't fit.
>
> A lot of progress could be made in baselining and understanding the living resources and possible oil and gas impacts if agencies were funded to work together to fulfill their mandates and put together the jigsaw puzzle of information.
>
> There is a poor understanding of long-term, chronic impacts of oil pollution. There is much more information on immediate and short-term impacts of the various oil and gas exploration, development and accidents than of medium and long-term impacts.

Information Opportunities

There are a number of possible opportunities to improve the knowledge and management of living natural resources as a byproduct of oil and gas exploration and development. Some ideas include improved:

> detailed mapping of habitat and stock information and detailed modeling of ecosystems to help identify areas for protection, as part of feasibility and planning;
>
> collecting detailed bottom terrain, composition and other habitat information, as part of oil and gas exploration, to input to ecosystem models;
>
> monitoring the ecosystem from offshore platforms - ocean monitoring [e.g. temperature, salinity, turbidity, flow direction and speed], biological monitoring [e.g. plankton, juveniles and passing fish, birds, marine mammals].

CONCLUDING COMMENTS

Offshore oil and gas exploration, development and production can't be undertaken without impacts on the environment and the organisms there. The issue is how much and what risks governments are willing to take, what contingency plans will be required, what populations will be put at risk, and how much will be invested in better understanding and addressing the risks.

At the Earth Summit in Rio, the precautionary approach or principle was agreed to be: *"Where there are threats of serious or irreversible damage, lack of full scientific certainty must not be used as a reason for postponing cost effective measures to prevent environmental degradation."* Canada has adopted the precautionary approach and made it formal government policy, including in the Oceans Act. Canada has specifically committed to a precautionary approach for conservation of fisheries resources and other living marine resources. It is not yet clear how this approach would apply to oil and gas decisions.

As oil spills, and possibly seismic exploration, could result in serious damage for many species in the QC Basin, and the damage could be irreversible for some local populations, by definition the precautionary approach should apply.

There is considerable scientific uncertainty about damage to the different life stages of many species. Part of the uncertainty is because the information currently available on marine fish, plants, birds and mammals and their habitats hasn't yet been brought together and assimilated to understand ecosystem interactions and possible short, medium and long-term impacts on most species. To adequately assess the biological implications of oil and gas exploration and development in the Queen Charlotte Basin will require bringing a number of databases together in a geo-referenced model or models of the area. For example, an expanded version of the Hecate Strait model for groundfish might be used to bring information on the various species together. This could provide the basis for assessing the impacts of various exploration and development strategies and potential accidents. It could also be used to help design and guide accident response strategies. This assimilation process would help to identify research priorities to reduce scientific uncertainty. In the longer-term, this early work would provide a basic baseline against which to assess impacts of oil and gas exploration and development, if it goes ahead.

Such a model or network of models could also be designed to receive data from real-time monitoring of the environment and ecosystem. This network of models would be a valuable tool for planning to use and manage the ocean and related land in the Basin. The model(s) could also incorporate information from the Global Ocean Observing System to provide a big picture awareness of global scale ocean changes that might be affecting conditions in BC.

As the current "lack of full scientific certainty" can't be used as a reason for postponing oil and gas exploration and development, then any strategy must include special actions to mitigate the risks of uncertainty. This should include all fail-safes and preventative actions possible, within the limitation of being cost effective. To reduce the risks, there should be serious investment in answering key outstanding research questions on the living resources in the area.

Within the spirit of the precautionary approach, "cost effective" is not just limited to the business aspects of exploration and development. Rather, it must also include the potential costs of cleaning up oil spills or trying to rebuild populations that are put at risk of extinction.

Another important aspect of the precautionary approach is assigning the burden of proof. Rather than the conservation authority or interests having to prove an adverse impact, the burden of proof should be on the proponent, whether government or industry, to prove no adverse impact. The proponent should have to answer conservation questions before development, not after problems can be demonstrated. Also, it is unclear who the burden of proof must be presented to – the conservation agencies, the government(s) or the public. However, if it were the government or government agencies, they would be in a conflict of interest as proponents of the development. This is currently a problem with industries such as aquaculture.

There is a tendency to be very critical of the oil and gas industry for the damage done to marine habitat and ecosystems, particularly by oil spills. The potential consequences of a major oil spill could be catastrophic for local ecosystems so require a highly risk averse approach. It is normal practice to have emergency measures plans, processes, and local equipment and crews to provide for all weather oil spill cleanup and to address other contingencies. It is also normal practice for the oil and gas industry to agree to compensation programs for any damages to the fishing industry. If requirements comparable to those for the oil and gas industry were applied to the fisheries, forest, aquaculture, transportation and tourism industries and to industrial and urban development, many of the existing adverse impacts on marine fish, birds, plants and mammals and their ecosystems would be moderated or eliminated. The impacts of these other industries tend to result in rather slower, less visible erosion of ecosystem capabilities that are difficult to prove cause and effect for, so they continue uncompensated. Can the same be expected for oil and gas?

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Appendix 16A: The Waterbird Perspective[47]

General
My comments will focus primarily on effects of spilled oil on waterbird populations. I have been involved with research on these issues since 1995, in the context of the *Exxon Valdez* oil spill in Alaska.

Review of JEWL Report
The JEWL report addresses only Atypical■ seabirds, i.e., storm petrels, cormorants, gulls, and alcids, and I consider this a major short-coming. There are many other birds in the area that would be affected by oil and gas development, and by any release of oil into the environment. Taxa of concern include loons, grebes, waterfowl (particularly sea ducks), and shorebirds. In particular, the loons, grebes, and sea ducks are especially vulnerable, given that (1) they spend much of their time floating on the ocean surface where contact with oil would occur, (2) they spend most of their annual cycle (8-9 months) on marine, nonbreeding habitats, where they could be exposed to spilled oil, (3) they occur in nearshore intertidal and shallow subtidal zones where any released oil would concentrate, and (4) the coastlines adjacent to proposed offshore development are valuable habitat for these species (particularly during nonbreeding seasons), likely supporting relatively high densities. In fact, bird populations considered to have not recovered fully from the *Exxon Valdez* spill include loons and harlequin ducks (a sea duck), as well as pigeon guillemots (a more typical seabird).

The JEWL report section addressing effects of oil in the environment on birds seems generally thorough and well researched. However, there is a sizeable body of work by Jenssen and colleagues regarding metabolic consequences of oil exposure in birds (summarized in Jenssen 1994) that was overlooked, and is quite important. Also, recent data from the *Exxon Valdez* should be included for a more comprehensive review (e.g., Esler et al. 2000a, Golet et al. 2002), especially with regard to long-term effects of catastrophic spills or effects of chronic, low-level exposure to oil (see below). In brief, the recent *Exxon Valdez* work indicated that oil was persisting in the environment much longer than previously thought. Beach surveys in Prince William Sound conducted by NOAA in summer of 2001 (12 years after the spill) detected residual oil on many beaches, in an apparently unweathered state. Further, evidence suggests that higher trophic levels, including sea ducks (Trust et al. 2000) and sea otters, continue to be exposed to *Exxon Valdez* oil. Finally, the data indicate that for some bird populations, the oil spill had long-term, population demographic consequences through direct and indirect pathways (Esler et al. 2000a, Golet et al. 2002). These data are contrary to the conventional paradigm that oil spill effects are limited to acute, short term consequences for bird populations.

Important Considerations
As development of offshore oil and gas is considered, and potential effects on the environment generally and wildlife in particular are debated, it is important to recognize that oil pollution can occur under different scenarios with different effects. As described above, short-term, acute effects of catastrophic oil spills are widely recognized as having effects on individuals and sometimes populations. However, long-term effects from spills and effects from chronic, low-level oil pollution are just beginning to be recognized as significant threats to bird populations. In fact, for some sensitive species, these less obvious effects are likely more damaging from a population-level perspective than one-time mortality in the wake of a major spill. This has important implications for considering acceptable levels of risk of chronic, small oil releases associated with offshore development.

Also, it is important to recognize that bird species will vary in their population responses to acute or chronic oil contamination, based on variation in life history and natural history attributes. For example, bald eagle populations apparently recovered within a few years following the *Exxon Valdez* oil spill (Bowman et al. 1995, 1997), whereas, harlequin duck populations remained unrecovered and still suffered continued injury at least 9 years after the spill. Interestingly, the ecologically similar Barrow's goldeneye showed fewer demographic responses to the spill (Esler et al. 2000b). These data indicate that subtle differences in habitat use, energetics, or life history strategy can have important implications for vulnerability to effects of oil, as well as recovery time following oil contamination. In general, species that occur in nearshore (vs. pelagic) habitats, eat invertebrates (rather than fish), have little metabolic flexibility, and have life histories oriented towards long reproductive life spans and relatively low annual productivity are those that are most susceptible to population-level effects.

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[47] Submission to Dr. Patricia Gallaugher, Member – BC Offshore Hydrocarbon Development Scientific Review Panel, prepared by Dan Esler Centre for Wildlife Ecology Simon Fraser University January 2002.

Similarly, effects of oil contamination can be expressed as (1) direct, continued effects (such as toxicity and associated mortality or effects on reproduction), (2) indirect, continued effects (such as changes to trophic webs), and (3) no continued direct or indirect effects, but full recovery constrained by the time necessary for a depressed population to return to pre-perturbation levels. Number 3 is rarely considered, but may be very important for long-lived species with relatively low intrinsic population growth rates. Hence, these effects should be considered when conducting risk assessment evaluations.

Finally, the criteria used for evaluating the health (and recovery status following a spill event) of populations and communities have been variable and controversial (Wiens et al. 2001, Irons et al. 2001). Occurrence of at least some individuals of most species has been considered appropriate (Wiens et al. 1996), while others have defined differences in demography and population trajectory as evidence of continued injury and lack of recovery (e.g., Esler et al. 2000a). This inevitably becomes a value judgement, and should be discussed in the context of risk assessment prior to development.

Recommendations for Research and Monitoring

If one lesson rings loud and clear from the *Exxon Valdez* experience, it is that pre-perturbation baseline data are absolutely critical for understanding what resources are at risk from development, as well as evaluating the population and community level consequences following development. In the context of considering offshore oil and gas development in BC, it seems that a critical part of the risk assessment procedure should include quantification of wildlife populations in the area. Further, this quantification should not be in the form of one-time distribution and abundance surveys, but also should include baseline information on demographic processes, population structure, and current contaminant/biomarker levels. Specifically, I recommend:

monitoring of seabird colonies for abundance and indices to productivity (e.g., chick growth); some of these data exist, although recent data are spotty for many sites.

monitoring of waterbird distribution and abundance, particularly during winter. Coastal BC is a globally important nonbreeding area for sea ducks, loons, grebes, and other birds. However, distribution and abundance have been poorly quantified, with replication over time and space practically nonexistent. Survey methodologies for similar environments and taxa have been developed (e.g., in southeast Alaska); these could be applied easily to the BC coast.

directed studies to quantify demographic processes. The importance of this can not be overstated. Studies of survival, movements, and productivity allow not only measures of population change, but also lend insight into the underlying mechanisms leading to that change. These are difficult, and often overlooked, but offer the strongest data for understanding how environmental change affects bird populations.

discern population structure; in other words, determine the size and spatial extent of the population segments that may be affected by environmental change. Again, this is a critical, but often overlooked, metric when considering both potential impacts of proposed development and effects of environmental change on populations. For example, a population of widely moving, interacting individuals will be structured at a fairly large scale, and local changes will likely have little effect on distinct population units. Conversely, species that show strong site fidelity and limited interaction will be structured at a much smaller scale, with demographically independent population units occurring within local areas that in turn are vulnerable to small scale environmental change or development. Population structure often is inferred from genetic information and movement data from marked individuals.

finally, evaluation of contemporary contaminant and biomarker levels (such as cytochrome P4501A for oil exposure; Trust et al. 2000), provides benchmarks for assessing contamination related to oil and gas development.

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Appendix 16B. Considerations for Seabirds in Western Canada, British Columbia, in regards to Offshore Gas and Oil Development[48]

Seabirds are among the most obvious members of the marine ecosystem, and they are commonly used as indicators for the health and condition of this huge habitat (Furness and Monaghan 1987) which is so difficult to survey and to monitor as a whole. Sea- and waterbirds are also among the most dominant victims when oil spills (Burger 1997) and other catastrophes occur. Therefore, these animals have attracted much of the attention in the public and scientific community (see also Wiens et al. 1984). The following sections of this short report, requested by the Centre for Coastal Studies, will review major points on what is currently known on seabirds (Campbell et al. 1990), seabird baseline data (Morgan et al 1991) and population estimates (Rodway 1991) for the waters of Western Canada, British Columbia. In addition, knowledge gaps will be identified and suggestions will be made how the current picture on Western Canadian seabirds in their unique and diverse habitat can be completed. This should help to assure that a solid, updated and internationally comparable situation could be reached safeguarding this unique ecosystem and their members.

Review of Seabird Population Estimates

Populations are rarely confined to bureaucratic and administrative units; this situation is particularly true for seabirds which migrate across borders and which move within the entire Pacific (e.g. Morgan et al. 1991); an ecosystem that underlies large-scale regime shifts (e.g. Thomson 1981). Besides major methodological topics on 'counting birds' (e.g. Bibby and Burgess 1992, Kepler and Scott 1981), the described situation on populations in administrative units fully needs to be reflected in the use of the term 'Population Estimates'. In concert with knowledge on distribution (Vermeer et al. 1988, Emms and Morgan 1994) and wildlife communities (e.g. Wiens et al. 1978, Huettmann and Diamond 2001), accurate population estimates are crucial for a sound management and assessment of human and natural effects (Wiens et al. 1984, Burger 1993). Approximately 16 species of seabirds are breeding on the coast of British Columbia (Campbell et al. 1990, Rodway 1991). It is not the objective of this brief review to address population estimates, population trends and further details for individual species. Overall, the Canadian Wildlife Service estimates that more than 5.5 million colonial birds nest at over 500 known locations. According to Morgan et al. (1990) (for reasons mentioned further in the text, the weak but only source for seasonal abundance estimates), the most abundant species are likely Sooty/Short-tailed Shearwaters, Gulls (California, Glaucous-winged, Herring/Thayer's), Black-legged Kittiwake, Common Murre, Auklets (Cassin's and Rhinoceros), Murrelets (Ancient and Marbled) and Storm-Petrels (Leach's and Fork-tailed). Species like Albatross (Black-footed, Laysan and Short-tailed), Thick-billed Murre, Horned Puffin, Brandt's Cormorant, other shearwaters (Flesh-footed, Buller's, Black-vented and Pink-footed) and Petrels can likely be considered to be rare in Western Canada. Nevertheless, these abundance estimates always need to be seen and interpreted in the global context. Except for Marbled Murrelets (Yen et al. in prep), almost all seabirds in B.C. breed on colonies, which are generally located on islands or directly at the coast (Campbell et al. 1990, Rodway 1991). However, most seabirds do not breed earlier than a minimum age of 2 years, frequently even at an older age, and colonies are only used by these seabirds for less than 3 months of the year. In most cases, less than 50% of the entire seabird population does actually breed. Therefore large numbers, if not even the majority, of seabirds in Western Canada are not accounted for when focusing alone on breeding seabird numbers on colonies (see Morgan et al. 1993 for pelagic (appr. >10km away from land) and winter survey and knowledge gaps).

Seabirds are an integral part of the ecosystem; they depend directly (e.g. Vermeer 1981, Vermeer et al 1985) or indirectly (e.g. as the key prey item for fish species) on plankton, which therefore presents the driving force for the overall marine food-chain seabirds depend on. However, except for prey information collected with relative ease from breeding seabirds at the colonies, no data exist on what seabirds prey on; this is particularly true for seabirds offshore and in winter. The waters of Western Canada are biologically among the richest in the Pacific, and thus attract vast and still unknown numbers of seabirds from the entire Pacific and beyond. Of interest to seabirds are normally 'breeding cliffs' and biologically rich areas, e.g. some unique shelf-, shelf-edge and coastal zones. Relevant areas include the rich waters off Vancouver Island, the calm fjords benefit from glacial run-off and strong tidal mixing, the undisturbed coastlines (e.g. compare also Vermeer et al 1998a), the 'hot vents' (sources of hot water on the sea floor, Thomson 1981), the Queen Charlotte Island Sound, and the Queen Charlotte Island region. The latter area, and specifically the eastern and southern sections of Queen Charlotte Island, is well known for its year round abundance of Pacific long-distance migrants (e.g. Sooty/Short-tailed Shearwaters, and to a lesser extent Black-legged Kittiwake) and of breeding birds (e.g. Storm-Petrels, Herring/Thayer's Gulls, Ancient Murrelet, Rhinoceros Auklet) (Morgan et al. 1990). Many more important and unique areas exist, e.g. around Triangle Island, but are usually not known due to lack of investigations and surveys. Currently, the seafloor of B.C. is not fully GIS-mapped even (see Huettmann and Lock 1987 for linking seabird occurrence with seafloor depth for management purposes). Nevertheless, these waters in B.C. are of global importance for many seabirds (A. Gaston pers. com.). Short-tailed Albatross and several shearwater and storm-petrel species present additional and major conservation topics (Melvin and Parrish 2001) which have not really been studied and monitored in Western Canada; topics like these can only be guessed from situations elsewhere, where these or similar species occur (Montevecchi et al. 1999, Wiese et al. 2001).

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Data Situation for Seabirds and Seabird Studies in Western Canada

Basic information and data on seabirds in Western Canada are available and do exist, e.g. to be found in the grey literature or in scientific publications (Rodway 1991), but many gaps and uncertainties remain. For seabird colony data and population trends, most of the information is either old (normally around 1989; contact D. Bertram for latest Cassin's Auklet and breeding seabird numbers on Triangle Island), or carry no or huge confidence intervals; they cannot always be used reliably for management and science since they are not fully accepted by experts (sensu Buckland et al. 1993, Reed and Blaustein 1997, Thomas and Martin 1996, Thomas and Juanes 1996, Thomas 1997). The best seabird colony information is given by Rodway (1991), with additional and more detailed information presented by Drent and Guiguet (1961), Campbell (1976), Campbell and Garrioch (1979), Rodway et al. (1988, 1990, 1992), Rodway and Lemon, (1990, 1991a b), Rodway et al. (1994). As outlined previously, seabirds counted on colonies do not present the entire population in the overall region. There is no survey in B.C. known to the author that combines seabird colony estimates with the remaining non-breeding and offshore population. Also missing are seabird density surveys (e.g. Tasker et al. 1984, Ford and Qualis 1984, Bibby and Burgess 1992, but see Vermeer et al. 1983), in order to obtain valid pelagic abundances (Vermeer et al .1987). Much of the colony information deserves major updates, valid statistical methodology and more intense and BC-wide survey methods (reference?). The proportion of surveyed animals on which inference on population trends is drawn tends to be very small, or ignores the overall Pacific population context (e.g. Vermeer and Devito 1989, Vermeer et al. 1989b). For the pelagic ocean, seabird surveys do exist and were partially published (Morgan et al. 1991); however, the survey intensity across time and space is low. Most of the spatial and temporal survey effort was driven by convenience and regions with potential threats from oil drilling (Morgan et al 1991) and does not capture the realities of the ecosystem (extend and changes). Therefore, it does not capture the entire picture and biological reality for seabirds in sound statistical terms as required for management. It can be concluded that many data gaps exist, and that many zoological surprises and new findings on seabirds in B.C. will still be made in the future. It can also be concluded that statistically sensitive findings such as trends or Canadian population estimates - major informations required for sound and transparent management and conservation - are not updated, nor available for many of the seabird resources. Thus, safeguarding seabirds in B.C. is currently not really possible, e.g. population targets do not exist or are unclear and highly debatable. In case of oilspills and other catastrophes, disagreements about their effects and impacts are likely to arise among experts and the public. This situation is not desirable and deserves clarification towards objective and accepted approaches and results.

Seabirds and Flaring on Offshore Platforms

For over millions of years oceans were not, or only marginally, affected by humans and therefore this habitat needs to be seen as a true 'wilderness' (Huettmann 2000a). Offshore oil drilling, oil platform structures and flaring (burning off gas) present a habitat change, a disturbance, never experienced by most members of the pelagic ecosystem and 'not supposed' to occur in a truly natural situation. Flaring activities can occur on such a magnitude that they can be monitored with satellite imagery (Muirhead and Cracknell

1984 in Wiese et al. 2001). Offshore oil drilling platforms can present an additional habitat ('artificial reef') in the feature-less ocean, which results into more abundant marine wildlife (Montevecchi et al. 1999 for a review; Wolfson et al. 1979, Shinn 1974; see Tasker et al. 1986 for seabirds). In addition, it is well known that light on the ocean during the night normally attracts plankton, fish and (sea-) birds (Wiese et al. 2001 for an overview; see also Keitt 2001, Keitt et al. 2001) alike; thus, marine wildlife is artificially high around these structures. Birds are believed to be attracted to and killed at (lightened) structures (Avery et al. 1980 for overview; Terres 1956, Weir 1976, Verheijen 1981), and be burnt directly by the flare (Sage 1979, Bourne 1979, Hope-Jones 1980, Crawford 1981, Wallis 1981, Wood 1999). Mitigation measures are hardly known, but see Reed et al. (1985). None of these effects are described and studied in Western Canada. In addition, passerine and shorebird migration and offshore flyways are not fully known for Western Canada, but should be considered for studies on the impact of flaring. Triangle Island (and certainly Farallon Islands off San Francisco) suggest already that a strong bird migration over the ocean exist, which is likely affected by flaring activities.

Research Suggestions to Safeguard Seabirds in Western Canada

Currently, pelagic seabird research and information on seabirds in Western Canada is not undertaken on Canadian and international standards. Considering the outlined shortcomings such as apparent lack of awareness on seabird issues in management circles, the entire lack of solid and statistically sound baseline ('pre-spill') data for the unique seabird resource in Western Canada, major efforts are required to bring Western Canada up-to-date to a decent and international standard. In the following, some topics are mentioned that should be considered for a sound science-based management:

> Holding a Workshop with international experts to review the state of seabirds in Western Canada and set priorities and budgets for scientific and holistic seabird research, its organization and management.
>
> It is crucial to define leadership for seabird resources, including their habitats and the entire marine ecosystem. Are DFO (Department of Fisheries and Oceans), CWS and the Provincial Governments (many Ministries) really looking effectively after seabirds? A definition and jurisdictional confirmation is needed towards a science-based multidisciplinary approach. DFO has never seriously supported and/or taken the lead on seabird issues ever in Canada, but is highly suggested to get involved (see also and Melvin and Parrish 2001).
>
> Long-term data collections and inventories are needed to provide sound baseline data (e.g. considering regime shifts), and are to be continued and intensified.
>
> Major effort to secure funds and cooperative project funding with partners beyond the governmental scope.

Additional research suggestions are given in the Annex

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ANNEX Additional Research suggestions

All interactions that seabirds have with their environment need to be understood in order to fully appreciate how oil development and flaring affects seabirds in Western Canada; therefore, seabird-fisheries interactions need to be known and studied in depth (e.g. Wahl and Heinemann 1979). This includes seabird movement studies and the effects of fishery discard and by-catch (Melvin and Parrish 2001).

Regular Beached Bird Surveys (e.g. Camphuysen 1989) are to be carried out at the entire B.C. coast, e.g. following strict survey formats used in Pacific Northwest (Hass and Parrish 2001) or Newfoundland (Wiese and Ryan 1999).

Compilation of all existing survey data in B.C., e.g. carried out earlier by contractors and agencies, into one database (e.g. Huettmann and Lock 1997) to obtain the best possible picture of historic seabird distributions and abundance. In addition, 'fragmentation' of seabird data in B.C. and Canada is to be avoided in the future by assuring collected data are centralized and available to the general public in a digital format.

High intense seabird surveys with valid sampling schemes, e.g Density Surveys (Tasker et al. 1984) and DISTANCE sampling (Buckland et al. 1993) and as used elsewhere and for other sea animals (sea mammals), are to be carried out. A valid survey design with strategic surveys, based on a group of trained and constantly evaluated observers, is necessary in order to obtain high quality survey data (Kepler and Scott 1981). Opportunistic surveys (vessels of opportunity such as B.C. ferries, cruise ships and research vessels), and systematic surveys (specifically repeated routes on DFO vessels, Coast Guard and others) could easily be used in a cost-effective manner.

In order to fill information and knowledge gaps for un-surveyed areas and for evaluation purposes, predictive GIS Modelling should be used (e.g. Huettmann 2000, Huettmann and Diamond 2001b, Yen et al. in prep). Results from this approach can be published as a (Canadian) Atlas, need ground-truthing and should then be used for future research, e.g. developing global change and fisheries scenarios.

Full inventories for seabirds, their prey and habitats, e.g. plankton, herring, sandlance and others (for Marbled Murrelets it would require coastal Old-Forest Inventories). These seabird abundances, habitats and prey data should be analysed with meaningful statistics, e.g. towards transparent ecosystem classifications and Marine Protected Area delineations.

A specific and science-based Western Canada GIS Data Center is to be set up for marine (pelagic and coastal) ecosystem data. DFO, Industry, NGO, governments (Federal, Provincial) and Conservation Data Centers (CDCs), could be contributing members.

Additionally, advanced research projects are to be carried out (applied questions and curiosity driven), e.g. behavioural effects of seabirds from additional food sources (flaring, fisheries), satellite-based seabird habitat studies, studying lesser known seabird species such as Storm-Petrels.

Appendix 17: Federal Government Responsibilities

Oceans Act

Canada's Oceans Act came into force January 31, 1997. Canada's Oceans Jurisdiction is described in the table below.

CANADA'S MARITIME ZONES

Overview:

The Act declares a contiguous zone and an exclusive economic zone.
Canada now has four maritime zones.

Under the Oceans Act:

ZONE

DEFINITION

RIGHTS & RESPONSIBILITIES

Territorial Sea (TS)

The TS extends 12 nautical miles from the baseline

Full rights and responsibilities may be exercised within this zone

Contiguous Zone (CZ)

The CZ extends 12 nautical miles from the outer edge of the TS

Canada's rights and responsibilities in this zone allow us to prevent and take action with respect to the commission of offences on Canadian territory relating to customs, sanitary, fiscal and immigration laws

Exclusive Economic Zone (EEZ)

The EEZ extends 200 nautical miles from Canada's baseline

Canada may exercise rights and responsibilities with respect to the exploration and exploitation of living and non-living resources of waters, subsoil and seabed in the EEZ; right to conduct marine scientific research; right to take measures to protect the marine environment

Continental Shelf (CS)

The CS includes the seabed and subsoil from the outer edge of the Territorial Sea to the outer edge of the Continental Margin, or to 200 nautical miles, whichever is greater

Canada may exercise rights and responsibilities with respect to the exploration and exploitation of mineral, and other non-living resources and of living resources (sedentary species only)

Appendix 18: Risk Assessment and Management[49]

1 Rational Decision-making and Risk Analysis

1.1 Decision-making

Since the present report focuses on risk aspects, a few comments on the methodology of rational decision-making would assist in the present report. Decisions under uncertainty consist of a choice of decision (for instance whether to drill a well), followed by chance events (for example a blowout), shown in Figure 1. The probabilities of the chance events, together with an assessment of the consequences, assist in the choice of an optimal decision.

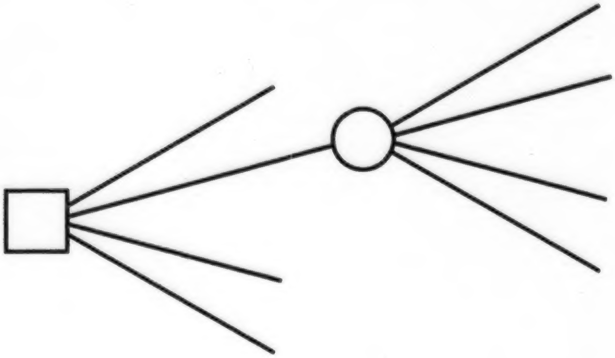

Figure 1 Decisions are indicated by rectangles and chance events by circles

1.2 Risk Analysis

Risk analysis is a branch of decision theory but the events under consideration are undesirable ones. As in decision analysis, risk analysis requires that consideration be given to consequences of actions as well as their probabilities. Taking a scale of consequences from 1 (most desirable) to 0 (least desirable), Figure 2 shows the region of interest in risk analysis. It is convenient to use probabilities calculated on an annual basis, so that, for example, the annual risk to an individual, or of an oil spill, is assessed. It is generally useful to express the probability on a logarithmic scale (lower part of Figure 2); usually the range under consideration is from about 10^{-2} to 10^{-7}, giving a range on the log scale of 2 to 7.

The consequence scale deals with events that might include single, several or many deaths and injuries, small or large oil spills, minor or major damage to the environment, or combinations of these. Aversion to risk and the consideration of utility can be built into the analysis. Decisions can be designed to reduce risk, for example, the decision not to permit the discharge of drilling muds and cuttings.

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[49] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Ian Jordaan and Associates – January 2002.

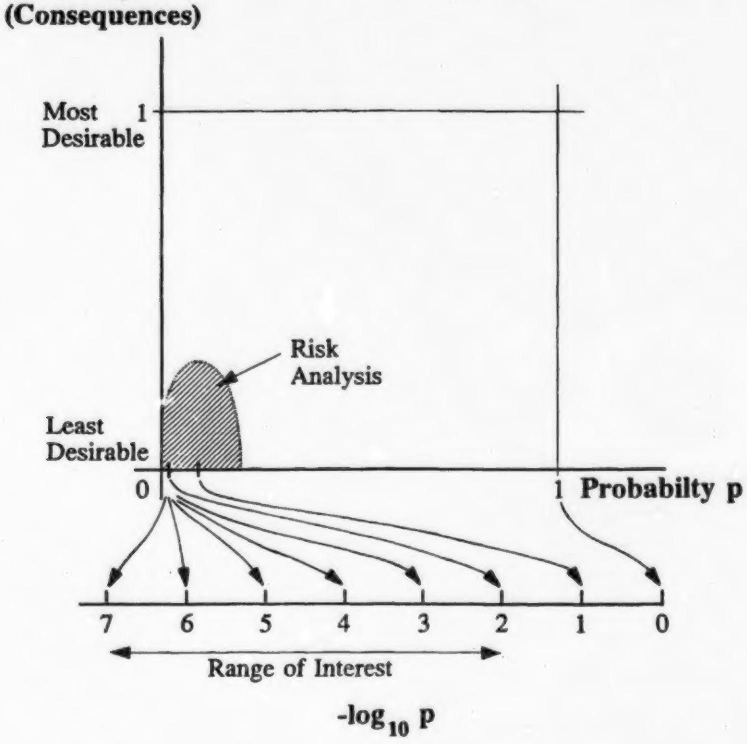
Utility
(Consequences)
Most Desirable
1
Risk Analysis
Least Desirable
0
1
Probabilty p
7
6
5
4
3
2
1
0
Range of Interest
-log10 p

Figure 2 Area of interest in risk analysis

2 Discussion of Reports

The 1986 report by an environmental assessment panel recommended that certain exploratory activities proceed subject to a large number of conditions and precautionary requirements. Nevertheless the moratorium continued. The 1996 report by the Canadian Ocean Frontiers Research Foundation reviewed technical and other progress since 1986. Many of the concerns regarding technical and administrative issues raised in 1986 have been addressed by developments and experience since then. Two further technical concerns were raised, the first regarding lack of understanding of biological resources at risk and the second the lack of risk evaluation and determination of acceptable standards. The JWEL report has been the main focus of the present effort. The report highlights the points of concern related to development in this area such as the affected marine life, climatic conditions, and hydrological conditions. It should be noted that environmental impacts in the area will also be a function of factors such as the regulatory environment regarding effluent discharges and type of drilling fluid to be used. In this area with a sensitive ecosystem these factors may have a significant effect.

The report, while identifying the relevant risks, does not constitute a quantitative risk analysis (QRA) which would permit the relative magnitude and importance of the various risks to be assessed. It is important for those involved in decision-making to understand the risks. For example, in dealing with oil spills, the exposure basis could be structured so as to assist in understanding. One might wish to determine the probability of a spill per unit of time (year for example) per activity (e.g. per drill rig). The unit of spills per "billion barrels handled" does not convey the risk for activities in the exploration phase. Further, the QRA approach would assist in dealing with the link between probability and severity.

The distinction between acute and chronic environmental effects is also of importance when assessing environmental risks. Oil spills are most likely to cause an acute environmental impact, that is the impact affects the ecosystem rapidly, such as oiling of marine mammals resulting in an inability to thermoregulate. These types of impacts can be prevented and mitigated with proper procedures. At the Aquatic Toxicology Workshop 2000 held in St. John's, NF it was shown that in the case of produced water discharges from platforms the long term or chronic impacts on the surrounding ecosystem are not well known and may be significant. This type of chronic impact would be especially important for low energy waters (i.e. shallow water, slow currents, etc…) where dispersion of the produced water plume is inadequate. The long term impact the platform and discharges may have on flora and fauna populations and marine animal migration, breeding and other activities are also difficult to quantify without a more detailed risk assessment.

For the purposes of the present activity, the JWEL report may be sufficient for decision-making. At the same time, it is recommended that a quantitative risk assessment focussing on probabilities and consequences be carried out either immediately or at a later stage in the process, before exploration proceeds.

2.1.1 Engineering Design

The area under consideration is prone to storms with high winds and associated waves and storm-driven currents. It is also an area of high seismicity. These facts have been discussed in the report. Current engineering practice can deal with these aspects which have been the subject of considerable research in recent decades.

One omission in the report is reference to the Canadian Standards Association (CSA) Code for Offshore Structures, currently being updated. The standard was formulated so as to achieve target safety levels of $(1 - 10^{-5})$ per annum. The loads specified for earthquakes, fore example, are set at annual probability exceedance of 10^{-4} per annum. (Standard S.471). The Canadian environment was very much the focus of this reliability-based standard. Some background information is given at the end of this appendix.

2.1.2 Quantitative Risk Assessment

As noted above, quantitative risk assessment would be most useful as a means to rationalize and set levels of safety for offshore activities. Certainly the methodology assists in identifying the most important potential impacts. The most significant of these is probably that of oil spills. This will be discussed as an example, in terms of probabilities and consequences. This is intended as an initial overview in conformity with the mandate to provide a review, and not a detailed analysis. We initially focus "attributes", and for this we consider volume of spill, which is of great importance.

2.1.2.1 Oil Spills—Probabilities

To gauge risk, one aspect is the probability associated with the events, linked to the attributes. A first point that should be made that the record has been improving, both in industry generally and in the offshore industry specifically. Data to illustrate this trend from the US Coast Guard is shown in Figure 3. This is for all spills in U.S. waters. Figure 4 shows the annual rates for various sizes of crude oil spill and for all substances including gas and light oils; data are from WOAD, (1996). (WOAD is DnV's Worldwide Offshore Accident Databank) for mobile offshore units. The rates for larger spills are declining over time. For the years 1980-1995, and for volumes in the range 118-1177 m^3, the rate is slightly higher that 10^{-4} per annum. The mobile offshore rigs are mostly used for drilling and the rate "per unit-year" provides a ready gauge of risk for a particular well-defined activity. It should be noted that probabilities are linked to the attribute under consideration, that is volume of spill in the present case.

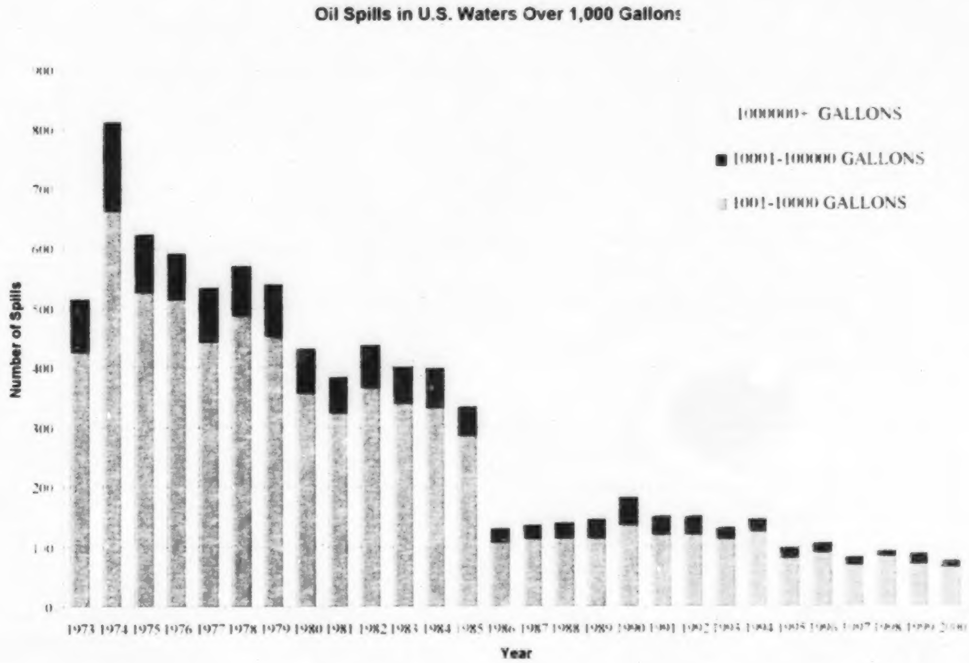

Figure 3 Trend showing declining rate for larger oil spills (U.S. Coast Guard data)

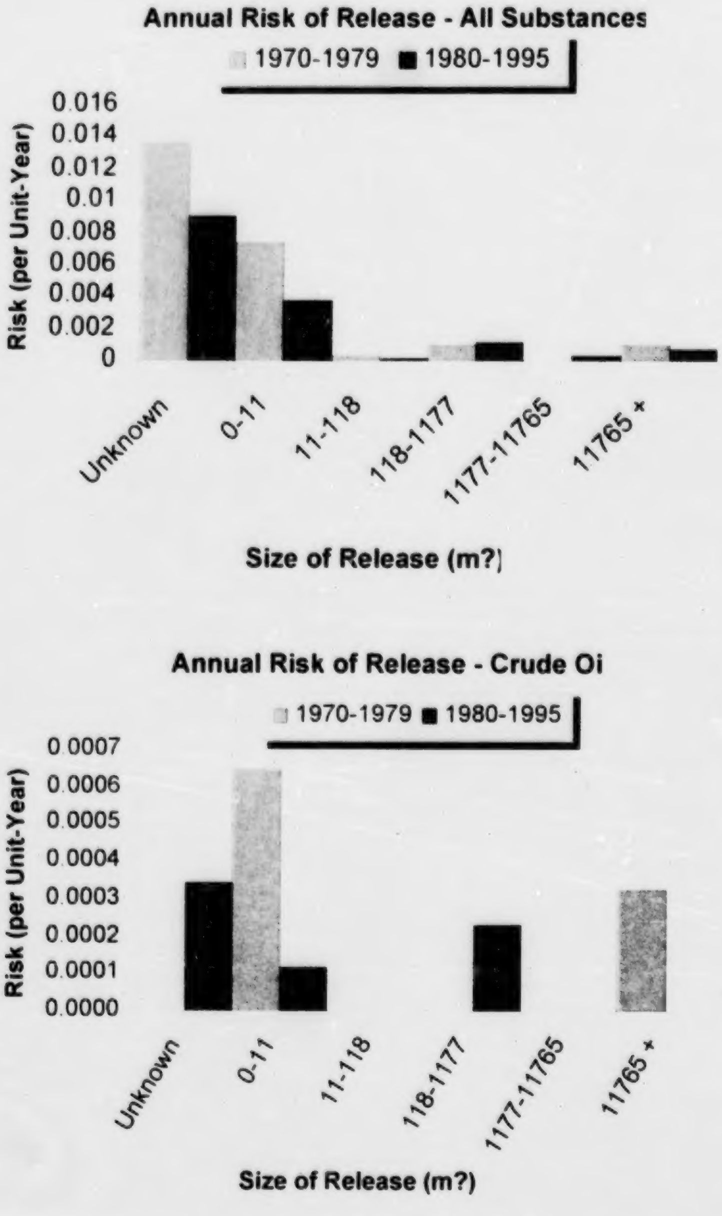

Figure 4 Crude oil and substance release statistics; mobile offshore units (WOAD)

2.1.2.2 Oil Spills-Consequences

In risk analysis, consequences need to be analyzed, in addition to the probability. We considered above the volume of the spill as the main attribute. Consequences should be linked to the attributes under consideration. The effect of oil spills in the marine environment is a function also of other parameters, including water conditions (temperature, salinity, currents, for example), climatic conditions, and type of oil spill (heavy versus light oil). For instance, a heavy oil spill where the temperature of both the water and air are low might result in the rapid formation of emulsions and tar balls which would have a much different impact than a lighter oil spill in a warmer environment (where evaporation may be more prevalent). Water and climatic conditions will affect the mechanism of oil transport (chemical, photochemical, and biochemical reactions) and physical processes (such as emulsification) and dispersion.

There are also chronic effects associated with oil spills, for instance an oil spill in a warm environment may be cleaned up rapidly through self purification processes. This process may result in a change of the ecosystem from one with very diverse flora and fauna to one of less diversity due to the conditions that favour a particular type of microorganism or plant life.

3 Conclusions

Offshore hydrocarbon exploration and development cannot be undertaken without impacts on the environment. The subject area is a sensitive one and care is needed in any development. The objective should be to maintain risks at an acceptable level and to mitigate them. There is sufficient evidence in the JWEL report to suggest that all of the risks have been identified. Safety has been improving in the industry and it seems reasonable to reconsider the moratorium. Techniques and methodology are available for dealing with risks. Decisions with regard to lifting the moratorium and proceeding with development can be taken on this basis. Before actual exploration and other activities take place, there is a need for quantitative risk analysis. This will provide an appropriate vehicle for decision-making in which the various stakeholders can assess the situation.

Risk analysis will also assist in defining the regulatory environment. Decisions can be made regarding (for example) procedures for mitigation of oil spills, effluent discharges and type of drilling fluid to be used. It is probable that the practice and regulatory environment in Canada is such that risks would be on the low end of the scale.

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Review of Risk Levels

With regard to risk to human life, the level "basic risk" R_0 is defined as the risk that is impossible to avoid in living in society. This is often taken as a proportion (about one-third) of the risks due to all accidents. Taking the value from Statistics Canada, it is found that

$$R_0 \cong 1.4 \times 10^{-4}$$

per annum. The level of 10^{-4} is often given as a desired maximum risk, for example Table 1, from Wells (1996). Figure 5 shows that, large accidents aside (from which lessons have been learned), the level of 10^{-4} is achievable in the offshore industry. Generally risk will be considered with regard to all causes and also with regard to a single cause (see for example Table 1)

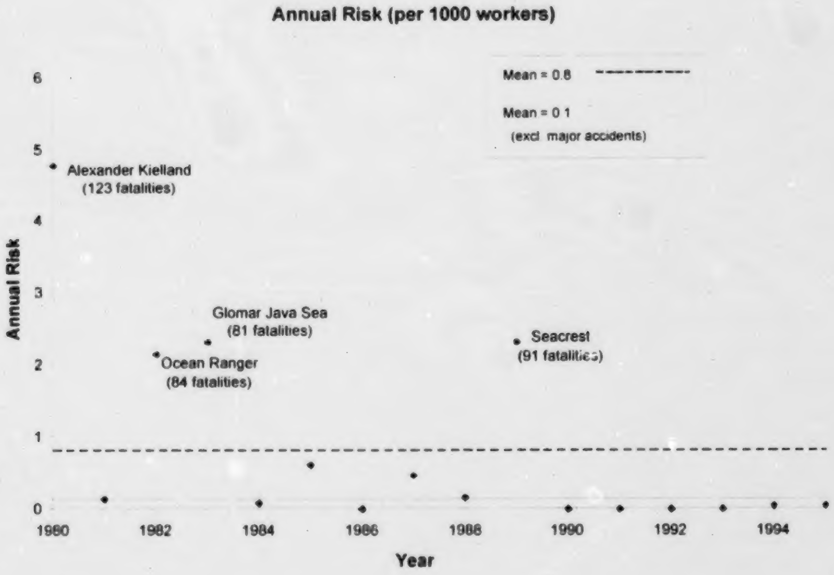

Figure 5 Risk for personnel on mobile offshore units (based on WOAD)

Table 1 Risk Values Recommended by Wells (1996)

Target values of maximum risk not to be exceeded	
Employee individual risk	
all process causes	10^{-4} per year
specific process causes	10^{-5} per year
Public individual risk	
all process causes	10^{-5} per year
specific process causes	10^{-6} per year
Risk of major accidents (that is societal risk)	
near miss from all process causes	10^{-4} per year
accident from all process causes	10^{-5} per year
catastrophic accident from all causes	10^{-6} per year
accident from specific process causes	10^{-6} per year
catastrophic accident from specific process causes	10^{-7} per year

Other scenarios other than those involving loss of life are of interest in the present case. In this regard, CSA (1992) treats "large loss of life" and "major damage to the environment as being equivalent.

Canadian Standards Association (1992) (currently being updated)

A brief summary of the safety aspects will be given pertaining to the Canadian Standards Association CAN/CSA-S471-92, General Requirements, Design Criteria, the Environment, and Loads, part of the Code for the Design, Construction, and Installation of Fixed Offshore Structures. This Standard sets the safety objectives for the code as a whole. An important aspect is the question of safety classes. These are defined in clause 4.5.2. The Standard defines two safety classes for the verification of the safety of the structure or any of its structural elements:

(a) Safety Class 1 - failure would result in great risk to life or a high potential for environmental damage, for the loading condition under consideration;

(b) Safety Class 2 - failure would result in small risk to life and a low potential for environmental damage, for the loading condition under consideration.

The main target safety level used in the calibration of the CSA code corresponded to a failure probability of 10^{-5} per annum. Target safety levels for safety class 2 and for serviceability (impaired function) were given as 10^{-3} and 10^{-1} per annum, respectively. Table 2 is reproduced here, from Appendix A of the Standard S471.

Table 2 Annual Exceedance Probabilities for Specified Loads

	Safety Class 1		*Safety Class 2*	
	Annual exceedance probability, p_E	Load factor	Annual exceedance probability, p_E	Load factor
Specified loads, E_f, based on frequent environmental processes	10^{-2}	1.35	10^{-2}	0.9
Specified loads, E_r based on rare environmental events	10^{-4} to 10^{-3}	1.0	10^{-2}	1.0
Specified accidental loads, A	10^{-4} to 10^{-3}	1.0	N/A	N/A

Appendix 19: Drilling History Offshore the Westcoast of British Columbia[50]

Summary

Between 11 June 1967 and 5 May 1969 Shell Canada drilled 14 exploration wells off the BC coast line in water depths ranging from 70 feet to 556 feet. Seven of the wells were located off the Tofino coast line, and the remainder were drilled in the marine portion of the Queen Charlotte basin. Most of this latter effort was expended in the Hecate strait.

The greatest range of water depths encountered were in the Queen Charlottes area, where two of the wells were in water so shallow that the Sedco rig was positioned on the sea floor. Elsewhere it was anchored.

For this study use was made of the time breakdown provided in all of the Drilling history reports filed with the BC government. There are several reasons why the data should be treated with caution.

> Drilling Tour sheets are not available: these would contain a much more detailed time allocation for the 12 hourly shifts, and form the basis for contract settlement between the operator (Shell) and the drilling contractor (Sedco). The Tour sheets are probably on file with the National Energy Board.
>
> Allocating rig time for purposes of contract settlement do not necessarily provide an unbiased view of the impact of the environment on drilling operations. Operational and contractual flexibility may have masked the impact of weather of sea state
>
> The preparation of the well history reports was not done to a rigorous standard, and the detailed of reporting varies from well to well.
>
> The history reports lack any detailed information on weather and sea states
>
> The history reports lack any information about sea floor conditions.

The well files in the possession of the National Energy Board are likely to contain far more information relevant to the interpretation of the information presented in the History reports. All that this paper can do is provide a first cut at describing what happened thirty three years ago.

Overview

Table I provides an overview of the wells and the time during which operations were carried out. This includes two winters' drilling seasons (67/68 and 68/69) when the weather could be expected to have a significant impact on offshore activities. This is confirmed by the two wells to which weather delays were attributed: -Zeus I-65, spudded on Feb 5 1968 (10 days Waiting on weather -"WOW") and Harlequin D-86, spudded on 17 September of the same year (17 days).

Overall operations became shorter in duration as the drilling program advanced. The first three wells too on average 63 days to drill and the last three took 22 days to drill. Not all wells were the same depth, but other factors appear to overshadow this aspect.

Rig moves

Table II provides rig move information. In the well records rig move time was always allocated to the next well. No rig move time was noted for the very first well (Prometheus). Rigmove time includes anchor handling and the move itself.

The accompanying figure suggests that weather impacts played no significant role. The two fastest rig moves took place during the winter months. However the two identified sprinters (Tyee N-39 and to Coho I-74) had two unique features: the rig moves were long (618 and 712 km respectively) and in both cases the rig was not anchored, but set on the sea bed. Anchor handling is time consuming portion of the overall rig move statistic and therefore would have a disproportionate impact on short rig moves. Without more detailed information it is difficult to derive weather related conclusions from this information.

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[50] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Bou van Oort, Senior Advisor, BC Ministry of Mines and Energy – January 2002.

Water Depth

Water depths are presented on Table III. For the Tyee N-39 well and the Coho I 74 well the rig was positioned on the floor of the Ocean as previously mentioned. The subsea BOP stack was nevertheless run, but the rotary table elevation above mean sea level was higher for these two wells than for the other wells. The stable platform thus obtained might permit operations under more severe conditions than for a floating location. Nine wells including these two apparently had no weather related delays.

No information is available in the well records on the quality of the sea floor at the various locations.

Mud Weight information

Table IV presents mud weight and drill penetration data. It will be noted that for the first few wells Shell used high mud weights of almost 18 lbs/gallon. The reason is not explained: was this deliberate or accidental? No mention is made of the planned mudweight in the drilling applications on record. A high mud weight has the apparent benefit of preventing unwanted influx of formation fluids, and therefore apparently reducing the risk of a blowout.

High mud weights do detract from formation evaluation because of the tendency to flush the bore hole wall with mud filtrate well ahead of the bit, and exposes the well to other drilling problems, such as stuck pipe and loss of circulation. This last item may increase the risk of a blow out by reducing the hydrostatic head for shallower, gas bearing formations. It is therefore perhaps no coincidence that the Pluto well encountered a shallow gas kick at about 1300 feet. The kick was controlled by closing the BOPs and it took only a 9.2 lb/gallon mud top control the flow. Such shallow gas pockets tend to be low volume events.

An added concern is the need to lace the mud with diesel oil to overcome differential pipe sticking problems (stuck pipe). This detracts from unambiguous chromatograph record interpretation of the returning mudflow.

A lower mudweight moreover tends to speed up bit penetration rate. Table IV demonstrates that Shell was alive to these concerns, and after the first Zeus well, changed its mud practices. The last few wells were drilled with 9-9.5 Lb/gallon mud. The table moreover indicates that drilling progress was materially improved by this change of policy; the penetration rate rose from about 200 ft per day to almost 500 feet per day. The Zeus I-65 well and the Murrelet L-15 well both achieved the same depth. A glance at the time statistics of Table I shows that overall operating days, and therefore including time lost for releasing stuck pipe, conditioning the mud, and coping with fishing jobs also was sharply reduced. This would suggest that the later wells were drilled in a less risky manner than the earlier wells.

Overall there is no indication that Shell encountered any serious problems specifically attributable to the unique environment they were operating in.

Bou van Oort

November 2, 2001

TABLE I: Rig time allocation overview

Well Name	Operating period		TD ft SSL	Total Time days	Time breakdown			
	From	to			Rig move days	Operating days	WOW days	Miscel days
Prometheus H-68	11-Jun-67	09-Aug-67	-7549	60	0	56	0	1
Pluto I-87	09-Aug-67	12-Oct-67	-12117	64	3	58	1	1
Zeus I-65	12-Oct-67	05-Feb-68	-9868	103	8	74	10	8
Zeus D-14	05-Feb-68	31-Mar-68	-7872	41	8	25	1	6
Tyee N-39	31-Mar-68	19-May-68	-11254	49	7	40	0	0
Sockeye B-10	19-May-68	22-Jul-68	-15540	64	2	60	0	1
Sockeye E-66	22-Jul-68	12-Aug-68	-9028	20	1	18	0	1
Auklet G-41	12-Aug-68	29-Aug-68	-7663	17	3	9	0	2
Osprey D-36	29-Aug-68	17-Sep-68	-8190	19	3	16	0	0
Harlequin D-86	17-Sep-68	01-Nov-68	-10521	45	9	18	17	0
Apollo J-14	01-Nov-68	22-Jan-69	-10040	81	49	32	0	0
Cygnet J-100	22-Jan-69	20-Feb-69	-7958	29	4	22	0	0
Coho I-74	20-Feb-69	05-Apr-69	-9005	32	8	24	0	0
Murrelet L-15	05-Apr-69	05-May-69	-9467	30	8	20	1	0

Time allocation per well

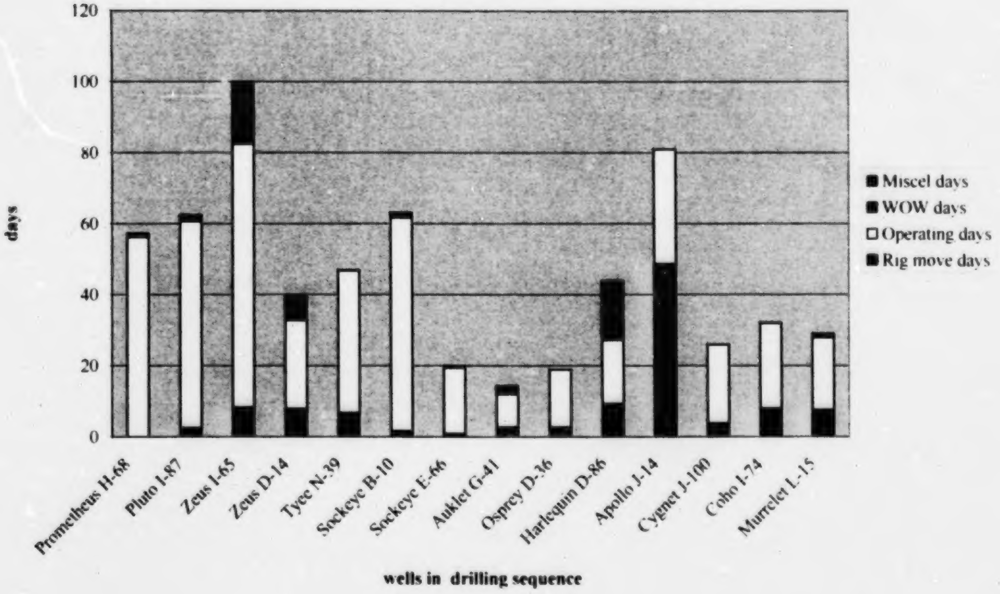


TABLE II: Rig moves

Well Sequence	Rig -move		to Well	Spud date	Rig move time Km/day
	km	days			
1	0	0.0	Prometheus H-68	11-Jun-67	0
2	41.5	2.5	Pluto I-87	11-Aug-67	16.6
3	15.5	8.3	Zeus I-65	04-Nov-67	1.9
4	7.5	7.9	Zeus D-14	24-Feb-68	1.0
5	618.0	6.8	Tyee N-39	07-Apr-68	90.7
6	60.0	1.7	Sockeye B-10	21-May-68	35.5
7	10.0	1.0	Sockeye E-66	23-Jul-68	9.8
8	51.5	2.7	Auklet G-41	14-Aug-68	18.9
9	120.0	2.8	Osprey D-36	01-Sep-68	43.0
10	57.5	9.3	Harlequin D-86	22-Sep-68	6.2
11	350.0	48.7	Apollo J-14	23-Nov-68	7.2
12	152.0	3.9	Cygnet J-100	26-Jan-69	39.5
13	712.0	8.0	Coho I-74	12-Mar-69	89.0
14	135.0	7.6	Murrelet L-15	13-Apr-69	17.8

Rig move Efficiency versus date

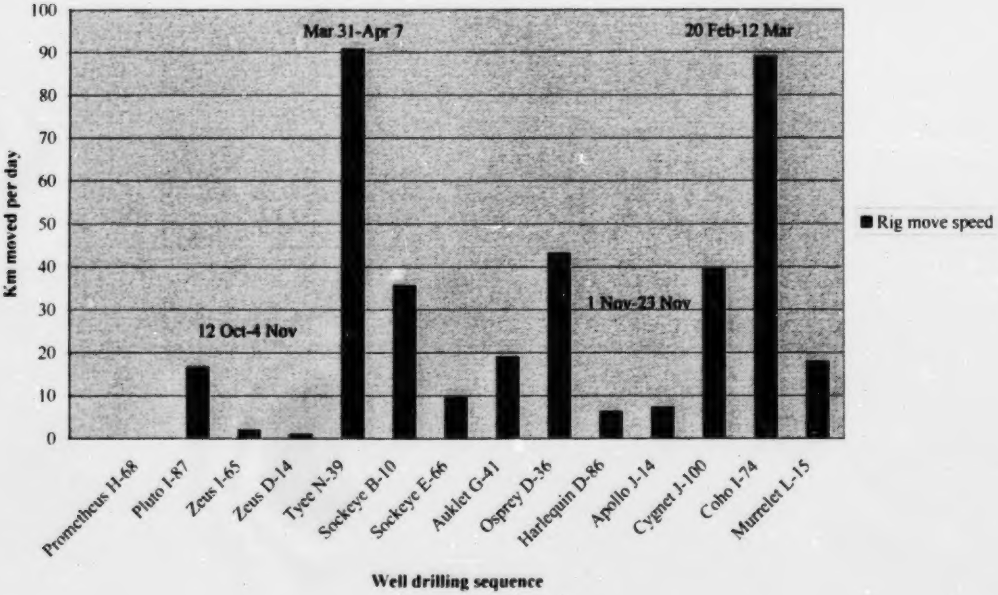


Table III : Water depths

Well Name	Area	Water Depth ft SSL
Prometheus H-68	Tofino	-181
Pluto I-87	Tofino	-197
Zeus I-65	Tofino	-323
Zeus D-14	Tofino	-459
Tyee N-39	Queen Charlottes	-90
Sockeye B-10	Queen Charlottes	-102
Sockeye E-66	Queen Charlottes	-183
Auklet G-41	Queen Charlottes	-556
Osprey D-36	Queen Charlottes	-192
Harlequin D-86	Queen Charlottes	-459
Apollo J-14	Tofino	-464
Cygnet J-100	Tofino	-485
Coho I-74	Queen Charlottes	-70
Murrelet L-15	Tofino	-364

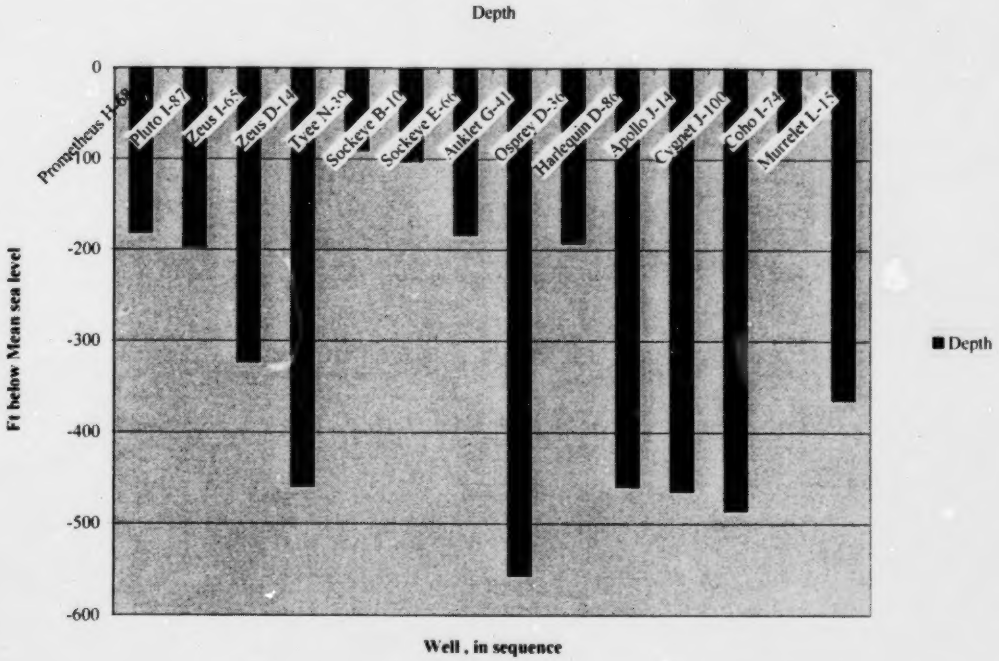
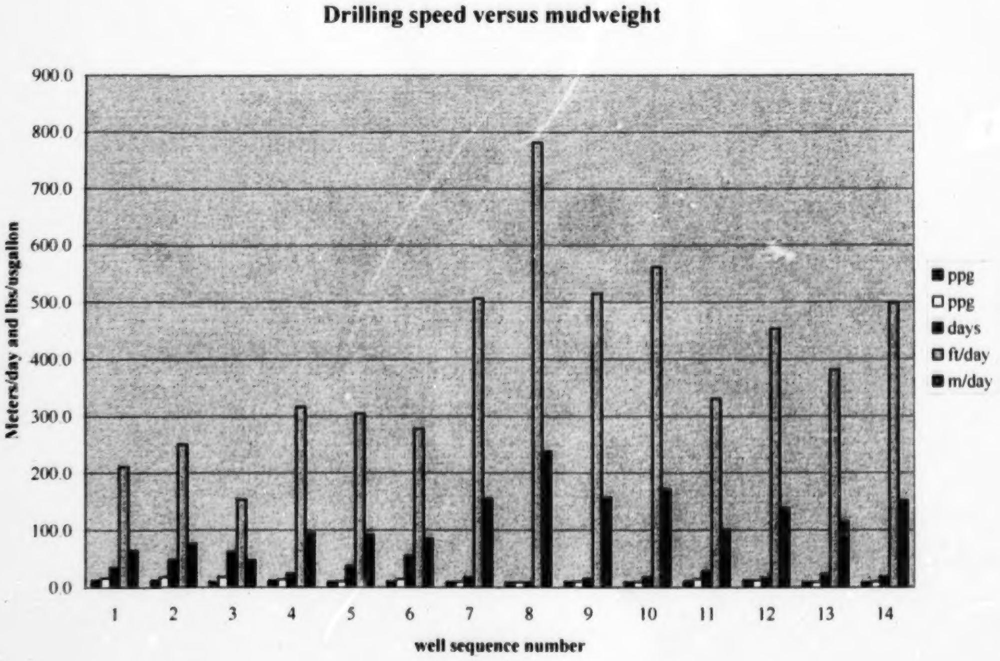


TABLE IV: Effect of mud weight on drilling

Well Name	mud weight from ppg	to ppg	Drilling efficiency days	ft/day
Prometheus H-68	12.3	16.6	34.9	211
Pluto I-87	12.3	17.9	47.7	250
Zeus I-65	9.2	17.7	62.0	154
Zeus D-14	11.5	13.5	23.4	317
Tyee N-39	9.6	10.0	36.7	304
Sockeye B-10	9.4	14.3	55.5	278
Sockeye E-66	9.1	9.4	17.5	507
Auklet G-41	9.0	9.0	9.1	780
Osprey D-36	9.8	10.4	15.5	515
Harlequin D-86	8.9	9.6	17.9	562
Apollo J-14	11.1	14.1	29.0	331
Cygnet J-100	13.0	13.0	16.5	454
Coho I-74	9.0	9.5	23.4	381
Murrelet L-15	8.9	9.5	18.3	498



Appendix 20: Lowell Statement on Science and the Precautionary Principle[51]

Growing awareness of the potentially vast scale of human impacts on planetary health has led to a recognition of the need to change the ways in which environmental protection decisions are made, and the ways that scientific knowledge informs those decisions. As scientists and other professionals committed to improving global health, we therefore call for the recognition of the precautionary principle as a key component of environmental and health policy decision-making, particularly when complex and uncertain threats must be addressed.

We reaffirm the 1998 Wingspread Statement on the Precautionary Principle and believe that effective implementation of this principle requires the following elements:

> Upholding the basic right of each individual (and future generations) to a healthy, life-sustaining environment as called for in the United Nations Declaration on Human Rights;
>
> Action on early warnings, when there is credible evidence that harm is occurring or likely to occur, even if the exact nature and magnitude of the harm are not fully understood;
>
> Identification, evaluation and implementation of the safest feasible approaches to meeting social needs;
>
> Placing responsibility on originators of potentially dangerous activities to thoroughly study and minimize risks, and to evaluate and choose the safest alternatives to meet a particular need, with independent review; and
>
> Application of transparent and inclusive decision-making processes that increase the participation of all stakeholders and communities, particularly those potentially affected by a policy choice.

We believe that effective application of the precautionary principle requires interdisciplinary scientific research, as well as explicitness about the uncertainties involved in this research and its findings. Precautionary decision-making is consistent with "sound science" because of the large areas of uncertainty and even ignorance that persist in our understanding of complex biological systems, in the interconnectedness of organisms, and in the potential for interactive and cumulative impacts of multiple hazards. Because of these uncertainties, science will sometimes be incapable of providing clear and certain answers to important questions about potential environmental hazards. In these instances, policy decisions must be made on the basis of sound judgment, open discussion, and other public values, in addition to whatever scientific information is available. We believe that waiting for incontrovertible scientific evidence of harm before preventive action is taken can increase the risk of costly mistakes that can cause serious and irreversible harm not only to ecosystem and human health and well-being, but also to the economy.

Some of the ways that scientific information is currently applied in formulating policy can work against the ability to take precautionary action, for example by misrepresenting limitations in the state of scientific knowledge. Decision-makers frequently look for high levels of proof of causal links between a technology and a risk before acting, so that their decisions will be protected from accusations of being arbitrary. But often, high levels of proof cannot be achieved, and are not likely to be forthcoming in the foreseeable future. A more complete and open presentation from scientists on the current limitations in understanding of environmental risks will encourage the acceptance on the part of government decision-makers and the public of the idea that precautionary action is a prudent and effective strategy when potential risks are large and uncertainties are large as well.

It is not only the communication between scientists and policy makers, however, which needs improvement. We believe that there are ways in which the current methods of scientific inquiry may also retard precautionary action. For example, research frequently focuses on narrow, quantifiable aspects of problems, thus inadvertently excluding from consideration potential interactions among different components of the complex biologic systems of which humans are a part. The compartmentalization of scientific knowledge further impedes the ability of science to detect and investigate early warnings and develop options for preventing harm when far-reaching health and environmental risks are involved. Unfortunately, limitations in scientific tools and in the ability to quantify causal relationships are often misinterpreted by government decision-makers, scientists, and proponents of hazardous activities as evidence of safety. However, not knowing whether an action is harmful is not the same thing as knowing that it is safe.

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[51] December 17, 2001. Statement from the International Summit on Science and the Precautionary Principle Hosted by the Lowell Center for Sustainable Production, University of Massachusetts, Lowell, Massachusetts, 20-22 September 2002

We contend that effective implementation of the precautionary principle demands improved scientific methods, and a new interface between science and policy that stresses the continuous updating of knowledge as well as improved communication of risk, certainty, and uncertainty. With these objectives in mind, we call for a re-evaluation of scientific research agendas, funding priorities, science education, and science policy. The ultimate goals of this effort would include:

> A more effective linkage between research on hazards and expanded research on primary prevention, safer technological options, and restoration;
>
> Increased use of interdisciplinary approaches to science and policy, including better integration of qualitative and quantitative data;
>
> Innovative research methods for analyzing the cumulative and interactive effects of various hazards to which ecosystems and people are exposed; for examining impacts on populations and systems; and for analyzing the impacts of hazards on vulnerable sub-populations and disproportionately affected communities. Systems for continuous monitoring and surveillance to avoid unintended consequences of actions, and to identify early warnings of risks; and
>
> More comprehensive techniques for analyzing and communicating potential hazards and uncertainties (what is known, not known, and can be known).

We understand that human activities cannot be risk-free. However, we contend that society has not realized the full potential of science and policy to prevent damage to ecosystems and health while ensuring progress towards a healthier and economically sustainable future. The goal of precaution is to prevent harm, not to prevent progress. We believe that applying precautionary policies can foster innovation in better materials, safer products, and alternative production processes.

We urge governments to adopt the precautionary principle in environmental and health decision-making under uncertainty when there are potential risks, as well as to take timely preventive and restorative actions in cases where damage has been demonstrated. The elements of decision-making processes incorporating the precautionary principle, as outlined above, represent necessary aspects of sound, rational processes for preventing negative impacts of human activities on human and ecosystem health. This approach shares the core values and preventive traditions of medicine and public health.

Annex A: Signatories (not included here)

Annex B: Wingspread Statement on the Precautionary Principle, January 1998

The release and use of toxic substances, the exploitation of resources, and physical alterations of the environment have had substantial unintended consequences affecting human health and the environment. Some of these concerns are high rates of learning deficiencies, asthma, cancer, birth defects and species extinctions; along with global climate change, stratospheric ozone depletion and worldwide contamination with toxic substances and nuclear materials.

We believe existing environmental regulations and other decisions, particularly those based on risk assessment, have failed to protect adequately human health and the environment, the larger system of which humans are but a part.

We believe there is compelling evidence that damage to humans and the worldwide environment is of such magnitude and seriousness that new principles for conducting human activities are necessary.

While we realize that human activities may involve hazards, people must proceed more carefully than has been the case in recent history. Corporations, government entities, organizations, communities, scientists and other individuals must adopt a precautionary approach to all human endeavors.

Therefore, it is necessary to implement the Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

In this context the proponent of an activity, rather than the public, should bear the burden of proof.

The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.